



Economic and Social Council

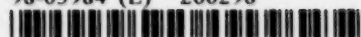
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**Committee on New and Renewable Sources
of Energy and on Energy for Development**
Third session
New York, 23 March-3 April 1998
Item 2 of the provisional agenda
Adoption of the agenda and organization of work

Provisional agenda

1. Election of officers.
2. Adoption of the agenda and organization of work.
3. Follow-up to the previous sessions of the Committee.
4. Energy and sustainable development:
 - (a) Environmentally sound and efficient fossil energy technologies;
 - (b) Renewable sources of energy with special emphasis on wind energy;
 - (c) Development and implementation of rural energy policies;
 - (d) Energy and transportation.
5. Medium-term planning and coordination of activities of the organization of the United Nations system in the field of energy.
6. Other matters.
7. Provisional agenda of the fourth session of the Committee.
8. Adoption of the report of the Committee on its third session.



Annotations

1. Election of officers

In accordance with established practice, the Committee may wish to elect a Chair, three Vice-Chairs and a Rapporteur.

2. Adoption of the agenda and organization of work

The provisional agenda was recommended by the Committee on New and Renewable Sources of Energy and on Energy for Development at its second session and approved by the Economic and Social Council in its decision 1996/304.

3. Follow-up to previous sessions of the Committee

Documentation

Report of the Secretary-General on the follow-up to the previous sessions of the Committee (E/C.13/1998/2)

4. Energy and sustainable development

(a) Environmentally sound and efficient fossil energy technologies

(b) Renewable sources of energy, with special emphasis on wind energy

(c) Development and implementation of rural energy policies

(d) Energy and transportation

In its resolution 1996/303, the Economic and Social Council emphasized the crucial role of energy in sustainable development, and the importance of adopting a proactive approach towards removing the obstacles and barriers hampering the development of new and renewable energy technologies.

Documentation

Report of the Secretary-General on environmentally sound and efficient fossil energy technologies (E/C.13/1998/3)

Report of the Secretary-General on renewable sources of energy, with special emphasis on wind energy (E/C.13/1998/4)

Report of the Secretary-General on the development and implementation of rural energy policies (E/C.13/1998/5)

Report of the Secretary-General on energy and transportation (E/C.13/1998/6)

Documentation for information

Note by the Secretary-General transmitting the report of the High-level Advisory Board on Sustainable Development for the 1997 review of the Rio commitments, entitled "Critical issues and policies for sustainable development: energy, transport and water" (E/CN.17/1997/17/Add.1)

5. Medium-term planning and coordination of activities of the organizations of the United Nations system in the field of energy

In its resolution 1996/44, the Economic and Social Council reaffirmed the importance of increasing inter-agency cooperation within the United Nations system, as well as coordination of activities for energy and sustainable development.

Documentation

Report of the Secretary-General on coordination of activities of the organizations of the United Nations system in the field of energy (E/C.13/1998/7)

Documentation for information

Report of the Secretary-General on an inventory of ongoing energy-related programmes and activities of entities within the United Nations system, on coordination of such activities, and on arrangements needed to foster the linkage between energy and sustainable development within the system (E/CN.17/1997/7 and Corr.1)

Report of the Secretary-General on possibilities of strengthening the coordination of the organizations and bodies of the United Nations system in the field of energy within the framework of the Administrative Committee on Coordination (A/52/175-E/1997/75)

6. Other matters

7. Provisional agenda for the fourth session of the Committee

8. Adoption of the report of the Committee on its third session

In accordance with General Assembly resolution 46/235, the Committee submits its report to the Economic and Social Council with policy options and recommendations.

**Economic and Social Council**

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12 February 1998

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**Committee on New and Renewable Sources
of Energy and on Energy for Development**

Third session

New York, 23 March-3 April 1998

Item 3(a) of the provisional agenda

Energy and sustainable development

**Follow-up to the previous sessions of the Committee on
New and Renewable Sources of Energy and on Energy
for Development****Report of the Secretary-General****Contents**

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I. Introduction

1. The Committee on New and Renewable Sources of Energy and on Energy for Development, at its second session, in February 1996, requested the Secretary-General to prepare a report on follow-up to the previous sessions of the Committee, for consideration by the Committee at its third session, in 1998.¹ The Economic and Social Council, at its substantive session of 1996, approved the provisional agenda and documentation for the third session of the Committee, as amended (see A/51/6 (Part II)). The present report has been prepared in response to that request.

II. Main decisions and recommendations of the Committee

2. At its first session, in February 1994, the Committee adopted a draft resolution on energy for sustainable development that underscored the linkages between energy and socio-economic development and the environment. In particular, it highlighted the linkage between energy and the objectives agreed upon in a number of forums in four main domains: development and socio-economic growth, environment, stability of market conditions conducive to economic growth, and natural resources.² The Committee observed that options existed for developing a new energy path through: (a) more efficient use of energy and energy-intensive materials; (b) increased use of new and renewable sources of energy; (c) more efficient production and use of fossil fuels; and (d) fuel substitution, from high-carbon to low-carbon or no-carbon fuels. It further observed that when used in environmentally sound and safe, economically viable and socially acceptable manner, the options provide a large potential for change.

3. In a draft resolution for adoption by the Economic and Social Council,² the Committee invited member States, intergovernmental and non-governmental organizations and the private sector to take specific measures with respect to the above-mentioned options. It requested the Secretary-General and the United Nations system to adopt all the necessary ways and means to promote the development of a world energy system compatible with sustainable development, and in that context to take specific initiatives.

4. With respect to coordination of activities in energy within the United Nations system, the Committee

recommended that the Secretary-General, *inter alia*, coordinate the exchange of information and experience on research, development and application of renewable technologies; improve the exchange of information on energy activities within the United Nations system; promote joint activities at the implementation stage of energy programmes within the United Nations system; improve the coordination of energy programmes within the United Nations system at the stage of programme budget formulation; make full use of the regional commissions in those coordination efforts; and promote the extension of coordination of energy activities outside the United Nations system.

5. The Economic and Social Council approved the Committee's request to convene a special session in its decision 1994/309 in order to provide advice on energy for rural development to the Commission on Sustainable Development at the Commission's third session (11-28 April 1995), when it was considering chapter 14 of Agenda 21 (Promoting sustainable agriculture and rural development), specifically concerning programme K.

6. In the report on its special session, the Committee requested the Commission on Sustainable Development to invite all States, entities within the United Nations system, other intergovernmental organizations to consider, as appropriate, a number of specific actions on a priority basis.³

7. The Committee, at its second session (12-23 February 1996), in draft resolution I, invited member States and entities within the United Nations system to consider convening a United Nations conference on energy for the twenty-first century in the year 2001 in order to mobilize world opinion for supporting actions at different levels on energy in relation to sustainable development. It also requested the Secretary-General to prepare a report examining the feasibility and the scope of the proposed conference, and to submit the report to the General Assembly for consideration at its fifty-second session.¹

8. In draft resolution II,¹ the Committee requested the Secretary-General to study the possibilities of strengthening the coordination of the organizations and bodies of the United Nations in the field of energy by the Administrative Committee on Coordination. It further requested the Secretary-General, in consultation with regional commissions and other entities within the United Nations system, to study ways to enhance the capability of the system in the field of energy for sustainable development, including the possibility of establishing a dedicated institution of expanding the mandate of an existing institution in order to meet this objective.¹

9. In draft decision I, the Committee also, 8 made a number of recommendations for action by the Council at its substantive session of 1996.¹

III. Follow-up to the decisions of the Committee and related initiatives

10. The report of the Secretary-General on follow-up to the previous sessions of the Committee on New and Renewable Sources of Energy and on Energy for Development to the second session of the Committee (E/C.13/1996/2) outlined the follow-up to the first and special sessions of the Committee by the Council, the Commission on Sustainable Development and a number of Governments. The present section is confined to the follow-up since then.

11. The Commission on Sustainable Development at its fourth session (18 April–3 May 1996), by decision 4/15 on protection of the atmosphere and protection of the oceans and all kinds of seas, requested the Secretary-General to prepare a report for consideration by the Commission at its fifth session, in 1997, covering an inventory of ongoing energy-related programmes and activities within the United Nations system, as well as proposals for arrangements, as appropriate, that might be needed to foster the linkage between energy and sustainable development within the United Nations system.⁴

12. The United Nations Educational, Scientific and Cultural Organization organized, in cooperation with entities within and outside the United Nations, a World Solar Summit held at Harare in September 1996. The Summit adopted the Harare Declaration on Solar Energy and Sustainable Development, and the outline of a World Solar Programme, 1996–2005, which has since been elaborated.

13. The World Bank has promoted energy sector reform and increased competition to foster greater efficiency in energy organizations and enterprises, while the Global Environment Facility is continuing to play a significant role in funding the incremental costs of projects that are related to global and environmental problems, including renewable sources of energy and energy efficiency. The principal thrust of the activities of the United Nations Development Programme in the energy area is to make energy services an instrument of socio-economic development as they impact on poverty reduction, environmental protection, generation of livelihoods and gender equality through an intensive focus on energy efficiency and renewable sources of energy.

14. The regional commissions have, by and large, shifted their activities to promote energy efficiency, the development of renewable sources of energy, and – in specific cases – improved, environmentally sound fossil fuel technologies.

15. Other entities, notably the World Meteorological Organization, the United Nations Industrial Development Organization and the United Nations Environment Programme have continued to provide assistance for capacity and institution-building in energy efficiency and energy conservation, as well as in the production of increased use of renewable sources of energy, while the International Atomic Energy Agency has, *inter alia*, provided assistance in comparative assessment of energy sources, health and environmental impacts, as well as risk of energy systems and analysis of cost of pollution abatement systems for electric power plants. The Food and Agriculture Organization of the United Nations has continued to provide assistance in the efficiency of production, transformation and use of energy, as well as the development of renewable sources of energy. The Department of Economic and Social Affairs of the United Nations Secretariat is continuing its activities for developing and applying energy intensity/efficiency indicators, facilitating the transfer of modern technologies for increased energy efficiency providing training in energy efficient methods and techniques, development and widespread use of renewable sources of energy, as well as undertaking studies on energy efficiency and conservation and providing advisory services at the request of Governments.

16. At its substantive session of 1996, the Economic and Social Council discussed at length the recommendations of the Committee and in its resolution 1996/44 on coordination of the activities of the organizations of the United Nations system in the field of energy, requested the Secretary-General to take into account the report and views of the Committee on New and Renewable Sources of Energy and on Energy for Development when preparing the report requested in decision 4/15 of the Commission on Sustainable Development. It also requested the Secretary-General to prepare a report, taking into account, as appropriate, the views of the Committee on New and Renewable Sources of Energy and on Energy for Development, on the possibilities of strengthening the coordination of the organizations and bodies of the United Nations system in the field of energy within the framework of the Administrative Committee on Coordination and to submit the report, through the Council, to the General Assembly for consideration at its fifty-second session. The Council, furthermore, requested the Secretary-General, in consultation with the regional

commissions and other entities within the United Nations system, to address in the same report the need to enhance the capability of the system in the field of energy for sustainable development, and to explore all possible options for a high-level discussion, in this context, taking into account the results of the fifth session of the Commission on Sustainable Development and of the special session of the General Assembly in June 1997, as well as guidelines provided by the relevant environmental conventions and their respective conferences of parties, in particular, the United Nations Framework Convention on Climate Change.

17. By decision 1996/303, the Council took note of the recommendations made by the Committee on New and Renewable Sources of Energy and on Energy for Development at its second session, and invited all States, entities within the United Nations system, other international organizations and non-governmental organizations to consider the recommendations, as appropriate. By its decision 1996/304, the Council took note of the report of the Committee, and approved the provisional agenda and the documentation for the third session of the Committee, as amended.

18. In response to the above-mentioned decision 4/15 of the Commission on Sustainable Development, a report of the Secretary-General entitled "Inventory of ongoing energy-related programmes and activities of entities within the United Nations system, on coordination of such activities and on arrangements needed to foster the linkage between energy and sustainable development within the system" was prepared and submitted to the Commission on Sustainable Development for consideration at its fifth session, in 1997. The Secretary-General also prepared a report on possibilities of strengthening the coordination of the organizations and bodies of the United Nations system in the field of energy within the framework of the Administrative Committee on Coordination (A/52/175-E/1997/75) for consideration by the Council and the General Assembly pursuant to the noted request by the Council.

19. The Government of Austria organized an expert workshop, attended by representatives from Governments, intergovernmental and non-governmental organizations, on fostering the linkage between energy and sustainable development within the international institutions, held at Vienna from 22 to 24 January 1997. The outcome of the meeting provided an invaluable input to the discussions of the fifth session of the Commission on Sustainable Development. More recently (29-30 October 1997), it organized informal consultations in connection with the preparation for the ninth session of the Commission on

Sustainable Development in the year 2001, and is planning an expert meeting on renewable energy in June 1998.

20. The General Assembly, at its nineteenth special session discussed at length, *inter alia*, issues relating to energy, transport and protection of the atmosphere, and decided that there was a need for a movement towards sustainable patterns of production, distribution and use of energy, and that in order to advance this work at the intergovernmental level, the Commission on Sustainable Development would discuss energy issues at its ninth session, in the year 2001. Preparations for the session should be initiated at the seventh session of the Commission, and should utilize an open-ended intergovernmental group of experts on energy and sustainable development to be held in conjunction with intersessional meetings of the eighth and ninth sessions of the Commission. The General Assembly also stressed the need for encouraging better coordination on the issue of energy within the United Nations system. Coordination issues are discussed at length in a companion report of the Secretary-General (E/C.13/1998/7).

21. On 12 March 1997, a letter from the Under-Secretary-General for Economic and Social Affairs was sent to Governments eliciting information on actions that they had taken in response to the decisions of the Committee, as adopted by the Council. So far, no response has been received.

22. At its substantive session of 1997, the Council considered the report of the Secretary-General on possibilities of strengthening the coordination of the organizations and bodies of the United Nations system in the field of energy within the framework of the Administrative Committee on Coordination. Interventions emphasized the importance given to energy by the nineteenth special session of the General Assembly. Delegations agreed that discussions that will take place within the Commission on Sustainable Development leading to the ninth session of the Commission in the year 2001 constituted a suitable response to the suggestion by the Committee on New and Renewable Sources of Energy and on Energy for Development to convene a United Nations conference on energy for the twenty-first century.

23. On 4 November 1997, a letter from the Director of the Division for Sustainable Development of the United Nations Secretariat was sent to the various entities within the United Nations system, requesting information on (a) the impacts of the decisions of the Committee (at its first, second and special sessions) on the work of the respective organizations in energy and related fields, and (b) the extent to which the reports of the above-mentioned sessions of the Committee

had been useful in the work of the respective organizations and the extent to which the organization had made use of such reports. So far, no response has been received from the entities within the United Nations system.

24. A number of non-governmental organizations have been active in the field of energy and have organized a number of meetings, workshops and symposia on energy, in particular in relation to the United Nations Conference on Environment and Development, and are planning future meetings on energy and sustainable development. Many of the deliberations are of interest to the Committee, and have provided valuable inputs to the past sessions of the Committee, as well as other intergovernmental bodies of the United Nations system. Many such organizations have expressed an interest in working closely with the Committee and the Commission on Sustainable Development in identifying key issues in energy for consideration at the ninth session of the Commission on Sustainable Development in the year 2001.

Notes

¹ See *Official Records of the Economic and Social Council, 1996, Supplement No. 4 (E/1996/24)*.

² *Ibid.*, 1994, Supplement No. 5 (E/1994/25 and Corr.1).

³ *Ibid.*, 1995, Supplement No. 5 (E/1995/25/Rev.1).

⁴ *Ibid.*, 1996, Supplement No. 8 (E/1996/28).

IV. Conclusions

25. The recommendations of the Committee have direct and indirect influence on activities in energy and related areas within the United Nations system, by other intergovernmental and non-governmental organizations, as well as by Member States. Many have paid increasing attention to energy efficiency, conservation and demand management and pricing policies, while others have contributed to the promotion and dissemination of clean energy technologies. Support for further introduction and application of renewable energy sources has increased substantially. Activities in the area of capacity-building and institutional development are increasingly linked to the broader context of socio-economic or environmental planning.

26. As can be seen from the discussion in section III above, other intergovernmental bodies of the United Nations system, namely, the Economic and Social Council, the Commission on Sustainable Development and the General Assembly, have discussed in depth the issues adhered to by the Committee and made recommendations consistent with those of the Committee to Member States, entities within the United Nations system, and other organizations, for action, as appropriate.



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Committee on New and Renewable Sources of Energy and on Energy for Development

Third session

New York, 23 March-3 April 1998

Item 4 (a) of the provisional agenda*

Energy and Sustainable Development

Environmentally sound and efficient fossil energy technologies

Report of the Secretary-General**

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* E/C.13/1998/1.

** More detailed information is available in the Division for Sustainable Development, Department of Economic and Social Affairs.



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I. Introduction

1. Most global energy needs today are provided by fossil fuels. Current practices of production, distribution and the scale of resource use threaten the assimilative capacity of the environment at local, regional and global scales. Thus, there is a clear need to increase the efficiency of fossil energy use, improve the environmental compatibility of fossil technologies, and shift to fossil fuels with lower environmental impacts, such as natural gas.

2. The world will have a secure supply of fossil fuels for more than 100 years; therefore, if measures are taken to realize the large potential for improving efficiency and to engineer a shift to advanced fossil fuel technologies as well as natural gas, many environmental problems will be mitigated. The present report does not evaluate the possible impact of such approaches on global carbon dioxide emissions: although widespread adoption of the improved technologies discussed would have a positive impact in moderating their growth, more comprehensive energy policies are needed to address that issue.

3. For almost two centuries, global primary energy consumption has grown at an average rate of about two per cent per year, doubling about every three decades: recently, between 1990 and 1996, it increased at an average annual rate of about 1 per cent (Nakićenović et al., 1996; British Petroleum, 1997).¹ Consumption has increased 34-fold since 1860, from about 260 million tons of oil equivalent (Mtoe) to 9 gigatons (or 9 billion tons) of oil equivalent (Gtoe) in 1990, including about 1.1 Gtoe of traditional energy forms, such as biomass, animal dung and wastes.

4. Most of the historical increase in global primary energy consumption has occurred in the developed countries, resulting in large consumption inequalities across the world. Their 25 per cent share of the world's population consumes almost 80 per cent of global energy. It is estimated that about two billion people in the world still do not have access to modern energy services. About 85 per cent of all energy used to date has been consumed by less than 20 per cent of the cumulative global population, mainly in the industrialized countries since 1860.

5. In 1990, 9 Gtoe of primary energy produced 6.4 Gtoe of final energy delivered to consumers, resulting in an estimated 3.3 Gtoe of useful energy after conversion in end-use devices. The delivery of 3.3 Gtoe of useful energy left 5.7 Gtoe of rejected energy (International Institute for Applied Systems Analysis and World Energy Council, 1995; Nakićenović et al., 1996; Gilli et al., 1995). Most rejected energy is released into the environment as low-temperature

heat, with the exception of some losses and wastes, such as the incomplete combustion of fuel. The global efficiency of converting primary to final energy is about 71 per cent. In the electricity sector, thermodynamic conversion efficiencies range from 32 to 34 per cent for single-cycle processes, and from 40 to 42 per cent from combined-cycle processes, while the ratio of final to useful efficiency is estimated at 52 per cent. The resulting global energy efficiency of converting primary to useful energy is 37 per cent.

6. Differences in energy efficiencies among regions are the result of many factors: energy mix, endogenous resources, pricing, level of economic development etc. Fossil fuels have relatively low conversion rates from final to end-use applications and relatively high rates from primary to final. The opposite is the case for electricity: it has relatively low primary to final efficiency but very high efficiency in end-use applications. Efficiency is highest in the developing economies (about 80 per cent) and lowest in economies in transition (69 per cent). The regional final to useful energy efficiencies range from 30 per cent in the economies in transition to 53 per cent in the market economies. Thus, even the most efficient technologies may not be sufficient to offset the energy-intensive lifestyles prevailing in very affluent market economies (Nakićenović, 1993).²

7. Generally, countries with lower per capita economic activity, measured at market exchange rates, have higher energy intensities (energy use in physical units per unit of gross domestic product (GDP)) than countries with higher per capita economic activity. Countries with very high rates of economic growth usually also exhibit high rates of energy intensity improvement, while economies with low or negative rates of growth have stagnating or increasing energy intensities.³ Developing countries are also characterized by a relatively high share of traditional energy use in total energy consumption. Considering only commercial energy in such calculations further reduces the apparent energy intensities of developing countries, but that measure may indicate increasing energy intensities for some of them. Even when such adjustments are made, there is a clear tendency towards diminishing energy requirements per unit of economic activity as GDP per capita increases for developing countries as a whole.

8. Assumptions about future efficiencies of energy technologies and their environmental impacts have a central role in energy and economic scenarios and projections. Morita and Lee (1997) have developed a unique database of energy scenarios and projections from all the available literature that includes about 400 different analyses of future energy and economic developments. The higher scenarios

of future energy requirements, both in 2050 and 2100, correspond to an annual growth rate of about two per cent, exactly in line with historical experience (Makarova et al., 1997).⁴ Furthermore, many scenarios assume continued growth in demand for fossil energy, although at a lower rate than total energy demand.

II. Fossil energy and the environment

9. Virtually all fuel cycles have negative environmental impacts. Combustion of fossil fuels is the largest source of atmospheric pollution, involving sulfur and nitrogen oxides, unburned hydrocarbons, particulate matter and carbon monoxide, all of which directly affect human health, as well as carbon dioxide. Such pollution arises in all stages of the fossil fuel cycles, starting with resource extraction through end uses, such as in automobiles and heating devices. Adverse impacts include health risks, accidents, pollution and global climate change.⁵

A. Health and accidents

10. Often, the underlying causes of adverse health and environmental impacts of energy derived from fossil fuels are associated with poverty. Indoor air pollution is a source of increased health risks that affects both urban and rural households, mostly in developing countries. The main source is the burning of biomass and coal for cooking and heating, with health risks being particularly high for women and children (World Energy Council, 1995a). The problem can be largely mitigated by improving the efficiency of cooking and heating stoves. That improvement could have the multiple benefits of reducing pollution, energy requirements and deforestation. However, the provision of efficient stoves is costly and sometimes encounters cultural and lifestyle barriers, so that only more fundamental social changes and – most importantly – development itself can really alleviate it significantly (World Energy Council, 1995a). There are also health risks to workers engaged in coal mining.

11. One of the risks of fossil energy, in addition to the health impacts of air pollution, is the occupational and public risk of mortality from all stages of the fuel cycle. Both immediate and delayed occupational risks are estimated to be distinctly higher for coal fuel cycles than for oil or natural gas. Occupational coal risks are substantially lower for surface compared with underground mining. In general, the immediate public risks are mostly associated with transportation accidents and adverse health effects from air

pollution. For energy transport, this means that dedicated energy infrastructures, such as pipelines, greatly reduce the public exposure to fossil fuel cycle risks.

B. Local, regional and global environmental impacts

12. Although the solution of urban and rural air pollution as a result of fossil fuel use will require creative and varied actions, there are a number of general and mostly structural future developments that could lead to further air pollution reductions.⁶ The basic premise is that with development, the main sources of air pollution would shift from distributed and varied small end-use sources to larger energy conversion technologies. Abatement measures would be cheaper and presumably also easier to implement for larger conversion systems, such as power plants (International Institute for Applied Systems Analysis and World Energy Council, 1995).

13. Historical experience shows that this has in fact occurred. Unfortunately, the resulting impacts have changed from indoor and local air pollution to regional and global environmental problems. Emissions of sulfur and nitrogen oxides, especially from large sources, such as power plants, have regional impacts, such as acidification of soil and water, a regional environmental problem of principal concern. The problem has been compounded by the fact that one abatement strategy often used to counter local air pollution problems has been “tall stack policies” for fossil power plants. And emissions of carbon dioxide have an impact on global climate change.

14. In the past, acidification has generally been regarded as a problem confronting mostly the industrialized countries (World Energy Council, 1995a). However, emissions are increasing to serious levels in many developing countries and with them damage due to acidification, particularly in parts of Asia and South America. If present trends continue, sulfur dioxide emissions for South and East Asia will exceed the combined emissions of North America and Europe in two decades. If nothing is done, widespread problems of acidification in Asia, such as reduced agricultural yields, are considered to be only a matter of time, and in some regions of China serious acid rain problems are already evident (World Energy Council, 1995a). Fortunately, awareness of the adverse environmental and human health problems associated with sulfur and particulate emissions is increasing throughout the world.

15. Effective measures exist for reducing sulfur and nitrogen emissions from power plants. The main issue is financing the capital requirement of such abatement measures. A shift from coal to natural gas would also reduce the emissions of both sulfur and nitrogen as well as carbon dioxide.

III. Fossil energy supply

16. Today, fossil fuels provide about 75 per cent of all primary energy consumed in the world. The most dominant fuel is crude oil, accounting for 33 per cent of the total, followed by coal and natural gas, accounting for 24 and 18 per cent of the total, respectively. The geological potential of fossil fuel resources is vast but finite. Their availability is, to a large degree, a function of extractive technologies.

17. Ultimately recoverable oil and natural gas deposits are large, and proven reserves are expected to increase in the future in line with growing oil and gas production (Rogner, 1997; Adelman and Lynch, 1997).⁷ Coal is known to be even more abundant, so that extraction is more a question of economic, environmental and other considerations rather than availability of appropriate deposits. Conventional oil reserves are limited by comparison. Much of the abundant occurrences of hydrocarbons consist of coal and unconventional oil and gas. Extraction and use of all fossil fuel sources of energy are associated with adverse environmental impacts. Thus, improvements in efficiency and environmental compatibility of fossil energy technologies are important prerequisites for utilization of such fossil fuels. This is especially important for developing countries rich in coal resources.

IV. Energy conversion and distribution

18. For the most part, fossil energy is not used directly but is first converted and transformed into electricity and fuels, such as gasoline, jet fuel, heating oil and natural gas delivered to end-users. More than a third of fossil primary energy is required for conversion and delivery to final users, and most of those requirements are for electricity generation. On average, the current global efficiency of electricity generation is about 30 per cent and of oil refineries about 90 per cent. Other forms of final energy delivered to households, such as coal and natural gas, require relatively little processing compared with electricity and oil products, so that their conversion efficiencies are high by comparison, ranging from about 60 to almost 90 per cent. Therefore, at

least from an efficiency point of view, the most important energy conversion processes are oil refineries and electric power plants. Efficiency improvements in those areas would significantly reduce overall energy requirements, emissions and possibly cost as well.

19. Improvement in conversion efficiencies is an important measure for reducing primary energy requirements per unit of energy service, and also for reducing the amounts of fuel required and the environmental impacts at all scales. Technological change, together with prudent maintenance and operating practices, are among the key factors for increasing conversion efficiencies. Crude oil refining, for example, is an energy-intensive process that uses refining by-products as a source of energy as well as purchased energy forms, such as electricity and natural gas. As noted, the average efficiency of oil refining is about 90 per cent in the Organisation for Economic Cooperation and Development (OECD) countries, but refinery efficiency can vary significantly, depending on the type of crude oil being processed and the design of the refinery: efficiency can be as low as 80 to 85 per cent in some developing countries. Refining efficiencies have improved considerably, however, during recent decades: at a rate of about one per cent per year in North America and about 1.5 per cent per year in the developing countries. The potential for improvement is considerable; improvement potentials for efficiency are estimated at 20 per cent by 2010 and more than 30 per cent by 2020 (World Energy Council, 1995b). However, one obstacle is the high capital costs of highly efficient technologies for complex refineries. According to a recent World Energy Council (1995b) report, advanced refinery capacity costs are in the region of about \$70,000 to \$90,000 per ton. In an industry where payback periods for new investments are about five years, efficiency investments may not always be competitive with other alternatives.

20. Historically, the efficiency of converting fossil fuels to electricity has increased dramatically. Today, fossil fuel power plants generate power from steam and gas turbines, or a combination of the two in a combined cycle, and can achieve net efficiencies of almost 40 per cent, while the best available natural gas combined-cycle turbine power plants achieve more than 50 per cent efficiency. Efficiency gains have been achieved through technological improvements of conversion efficiencies, fuel switching from coal to natural gas, and change from steam engines to turbines and combined-cycle schemes. Another source of efficiency gains has been economies of scale. Conversion efficiency has increased by a factor of 10 in about 90 years, corresponding to an improvement rate of about 2.5 per cent per year.

21. Current technological measures to improve efficiency include the introduction of combined-cycle, gas-fired plants and coal-fired plants with supercritical steam cycles. At the same time, environmental considerations often require the addition of flue-gas clean-up systems for pollutants, such as sulfur and nitrogen oxides, and in future perhaps also carbon scrubbers. Recent innovative plant design and integration have succeeded in both improving efficiency and reducing emission (over and above those directly linked to the efficiency factor). For example, integrated gasification combined-cycle (IGCC), pressurized fluidized bed (PFB) combustion technologies and fuel cells all reduce most of the emissions significantly, which eliminates or reduces the need for environmental add-ons.

A. Cleaner fossil fuel conversion technologies

1. Natural gas and combined-cycle

22. Today, the most economically and environmentally sound fossil power plants are natural gas combined-cycle plants. The most efficient units now on the market achieve conversions of 95 per cent and 52 per cent net efficiency. Further efficiency improvements by a few percentage points are expected in the next few years. Combined-cycle technology represents a hedge against the uncertainty of future environmental policy priorities, and it also represents a least-regret cost-effective investment strategy. That is, the economics of combined-cycle technology are affected by three factors: (a) the availability of low-cost natural gas or fuel oil, (b) environmental policies mandating lower emissions, and (c) relatively low capital costs.

2. Cleaner and more efficient coal technologies

23. Another way of achieving high conversion efficiencies and low emissions is the use of coal in conjunction with combined-cycle technology. In essence, most clean coal technologies involve the marriage of gas turbines and coal or coal-based fuels (Bajura and Webb, 1991). Clean coal technologies fall into several categories: clean combustion processes, such as PFB technologies; coal gasification and combustion of the synthesis gas in a combined-cycle gas turbine; direct and indirect coal-fired turbines; fuel and pure oxygen gas turbines; magneto-hydrodynamic (MHD) generators; carboniferous fuel cells; and the separation of hydrogen from coal (hydrocarb process). PFB technologies and such integrated systems as IGCC technologies are either already operational or rapidly approaching the stage of commercial availability. Direct coal-fired systems are in the prototype development stage. The same is true of fuel cells,

while MHD generator development and hydrocarb process are in the proof-of-concept stage.

B. Comparison of cleaner fossil fuel technologies

24. The table summarizes the salient characteristics of the clean fossil technologies that are likely to contribute to the improvement of energy conversion efficiencies during the next decades and to a reduction of environmental impacts at all scales, as well as representative estimates for economic and technical characteristics of those technologies. Unfortunately, there are few really comparable data sources in the literature.

25. Clearly, the characteristics of the combined-cycle natural gas power plants and the conventional coal power plants could vary from location to location due to many different factors, and the numbers shown are indicative of the costs and performance of such facilities. The situation is quite different for technologies still under development. The likely characteristics of such facilities are not known with any degree of certainty, and their cost data are particularly speculative. They are given so as to show orders of magnitude but may clearly change radically until such power plants can be purchased commercially.

26. The table provides estimated capital, fixed and variable costs of clean fossil technologies, many of which are still at a developmental stage indicating an electricity generation cost range of about three to more than six cents per kilowatt-hour. The lowest costs are for electricity generated by natural gas combined-cycle power plants. The electricity generating costs are given with and without fuel costs. Fuel costs are based on an acquisition price of \$50 per ton of coal (\$54 per kilowatt-year) and \$2.5 per million British Thermal Units (\$75 per kilowatt-year) of natural gas (including transportation costs), again indicating the inherent uncertainty associated with such estimates. Indeed, some of the large differences in capital costs of the clean fossil technologies are balanced by differences in fuel costs (International Atomic Energy Agency, 1991). Technologies with high capital costs tend to have lower fuel costs. The lower capital costs of combined-cycle technology give more financing flexibility for utilities that have to raise capital that competes with other investment opportunities. This also demonstrates some of the economic advantages of combined-cycle technology in current market conditions.

27. The thermal efficiency of advanced fossil power plants exceeds 40 per cent, and goes beyond the 55 per cent mark

Characteristics of cleaner fossil electricity generating technologies

(Estimated costs in 1990 United States dollars)

System	Units ^a	Conventional coal	PFBC coal	IGCC coal	DCFT coal	ICFT coal	Combined-cycle natural gas
Power	MW	400	400	1 250	200	200	400
Capital cost	\$/kW	1 300	1 750	1 350	2 100	1 430	650
Fixed O&M cost	\$/kW/yr	36.4	56	37.8	71.4	30	16.3
Variable O&M cost	\$/kWyr _e	42.9	26.3	27.2	30.7	25.4	5.9
Efficiency	%	38.8	45	44.3	43.2	51.7	52.6
Fuel use	BTU/kWh _e	8 800	7 600	7 700	7 900	6 600	6 490
Fuel cost	\$/GJ	2.05	2.05	2.05	2.05	2.05	2.4
Life time	years	35	30	35	30	35	35
Load factor	%/yr	80	80	80	70	75	80
Cost (excl. fuel)	\$/	0.0229	0.0291	0.0218	0.04	0.0196	0.0094
Total electricity generating cost	\$/kWh _e	0.0468	0.0486	0.0415	0.0608	0.0368	0.0265
Carbon emissions	kgC/kWh _e	0.232	0.2	0.203	0.208	0.174	0.109

System	Units ^a	MHD coal	MCFC coal	MCFC natural gas	SOFC coal	SOFC natural gas
Power	MW	150	650	200	165	165
Capital cost	\$/kW	2 600	1 650	1 150	1 240	860
Fixed O&M cost	\$/kW/yr	78	16.5	15	12.4	11.2
Variable O&M cost	\$/kWyr _e	87.6	92	87.6	78.8	74.5
Efficiency	%	55	50.5	52.9	49.7	54.2
Fuel use	BTU/kWh _e	6 200	6 750	6 450	6 860	6 300
Fuel cost	\$/GJ	2.05	2.05	2.4	2.05	2.4
Life time	years	30	30	30	30	30
Load factor	%/yr	70	75	75	75	75
Technology cost (excl. fuel)	\$/kWh _e ac	0.0535	0.0313	0.025	0.0246	0.0197
Total ac electricity generating cost	\$/kWh _e	0.0769	0.0564	0.0153	0.0484	0.0442
Carbon emissions	kgC/kWh _e	0.163	0.178	0.108	0.181	0.106

Note: DCFT = direct coal-fueled turbines; ICFT = indirect coal-fired turbines; IGCC = integrated gasification combined-cycle
 PFBC = pressurised fluid bed combustion; MCFC = molten carbonate fuel cells; MHD = magneto-hydrodynamic
 SOFC = solid oxide fuel cells; O&M = operating and maintenance

^a MW = megawatt, kWh = kilowatt hour, BTU = British thermal unit, GH = gigajoule, kgC = kilograms of carbon, _e = effective

for fuel cells (future fuel cells may reach efficiencies above 60 per cent (International Atomic Energy Agency, 1991), which would effectively double the current average efficiency of electricity generation). The current average efficiency of coal power plants in OECD countries is almost 39 per cent, approaching the performance of modern conventional coal power plants. In contrast, the global average efficiency of coal power plants is about 33 per cent or almost 20 per cent lower than the conventional reference plant. As modern power plants increase their market share, the potential for improvement in average efficiencies is large.

28. Some of the designs of advanced coal power plants are approaching commercial maturity. Compared to the current average global efficiency of coal power plants, such advanced designs imply an efficiency improvement potential of almost 40 per cent, and would also emit drastically less particulate matter, sulfur and nitrogen oxides, and almost 40 per cent lower carbon dioxide emissions. Efficiency improvements are a very effective method of decreasing the environmental impacts of energy use at all scales, including emissions of sulphur dioxide, nitrogen oxides and carbon dioxide, without necessarily increasing the cost of electricity.

29. This comparative assessment of advanced fossil electricity generation technologies indicates that the most cost-effective choice today across a range of different local and regional conditions is combined-cycle natural gas power plants. That situation will not change for some time. Most of the other advanced technologies are expected to have higher capital costs, but in some cases these may be a decreasing function of scale. However, natural gas is the preferred energy source, in conjunction with combined-cycle technology, where natural gas is available. On a large scale, i.e., greater than 500 megawatts, a combined system of IGCC and MHD technologies may emerge as a viable option. Furthermore, natural gas has the lowest environmental impacts of all fossil energy sources: its sulfur dioxide emissions are minimal, its nitrogen oxide emissions can be controlled and its carbon dioxide emissions are the lowest of all the fossil fuels. The main problem is the leakage of methane, a potent greenhouse gas. Fortunately, pipeline leaks are kept low if for no other reason than safety, and other sources of methane can be controlled effectively. Clearly, the availability of natural gas is an issue in many parts of the world, either because domestically it is not an abundant or developed source of energy, or there are no acceptable import possibilities, or the appropriate infrastructure for transport and distribution does not exist.

V. Energy distribution and end use

30. The structure of energy end use is of crucial importance for the overall efficiency of fossil energy from source to service. The purpose of conversion of primary energy to final energy forms is indeed to facilitate higher efficiencies and greater convenience and reduce the environmental impacts of energy end use. In fact, the efficiency of final energy use can be more important for the overall efficiency of the full fuel cycle than the upstream efficiencies themselves. Obviously, end-use technologies, such as motor vehicles, are intimately linked to particular fuels. More often than not, such technologies limit the flexibility for switching between different sources of primary energy and fossil fuels. The question is, therefore, which combination of end-use technologies and associated fossil fuel cycles could provide the full range of required energy services in the future with the highest overall efficiencies, economically and with low environmental impacts. Based on an assessment of efficiencies, total cost and carbon dioxide emissions for a number of end-use applications and their fossil fuel cycles, it is evident that electricity is the final energy of choice for combining different fossil fuels with different (stationary) end-use technologies.⁸

31. Since fuel cycles are driven by the demand for energy services, attention must be given to improving the performance of end-use devices. Thus, demand-side management and other measures to improve the efficiency and reduce costs of energy end use are at least as important as upstream improvements. The existence of large opportunities for demand-side management and improved end-use efficiencies raises the question why they have remained substantially unexploited. Evidently, barriers exist, especially in developing countries, involving a variety of market allocation failures, pricing policies, institutional impediments, consumer awareness, incentive structures, access to credit and infrastructural constraints. Current approaches do not adequately address those issues.

VI. Technological and socio-economic policies

A. Technological change and learning

32. High rates of innovation in the energy sector are a prerequisite to meeting the ambitious requirements for increasing the quantity and quality of energy services and

at the same time significantly lowering the costs and adverse impacts of many technology options. However, over the last decade, public-sector support for energy research, development and demonstration has declined by one third in the OECD countries and by half a percentage of GDP (Watson et al., 1996). Fortunately, energy technologies require relatively modest investments in research, development and demonstration. Some advanced fossil technologies are of small scale and modularity, which promise high rates of learning with relatively modest investments.

33. Research, development and demonstration programmes are necessary but not sufficient to establish new technologies in the market place. Commercial demonstration projects and programmes located in realistic economic and organizational contexts to stimulate markets for new technologies are also needed. Both research, development and demonstration efforts and commercial demonstration and deployment, especially in niche markets, require coordinated initiatives from both private and public sectors, and a range of market and regulatory measures and policies.

B. Other fossil energy policies and measures

34. The diffusion of advanced, clean and efficient, fossil energy technologies over and above the technology performance improvements that accompany the natural replacement of depreciated capital stock in the energy system is unlikely to occur without appropriate policy instruments and measures.

35. Capital scarcity, especially in the developing world and some countries undergoing economic transition, is a major barrier to the adoption of advanced energy technologies. In addition, energy supply technologies compete with other development needs for limited capital. However, many energy options could involve endogenous technology production, creating new local infrastructure and employment. Even in the industrialized countries, the capital used for financing energy supply technologies may yield lower returns than other investment opportunities. Measures that make supply and conversion technologies more attractive in the market place would help to resolve some of the financing difficulties by reducing risk, uncertainty, and upfront capital requirements. Other helpful measures include accelerated depreciation, start-up loans and concessional grants.

36. The removal of institutional barriers is also often a crucial step for attracting private-sector interest in advanced technologies. Regulatory reform and deregulation (breaking-

up of producer monopolies, transmission and distribution networks) have allowed small and independent power producers access to the grid and improved their competitiveness. Standardization of equipment to facilitate connection to the grid would also improve technology adoption.

VII. Future improvement of fossil energy technologies

A. Improvement potential of fossil technologies

37. Numerous studies indicate that 10 to 30 per cent energy efficiency improvements above present levels are feasible at little or no net costs in many parts of the world through technical change and improved management practices over the next two to three decades (Watson et al., 1996a). An instantaneous replacement of the current energy system by the best available technologies would result in an overall efficiency increase of about 60 per cent, even without taking into account the most advanced technologies that are not yet available commercially. The realization of that potential would take about 70 years at the historical improvement rate of one per cent per year. However, within a period of 50 to 100 years, the entire energy supply system will be replaced at least twice. Thus, it is technically possible to realize substantial performance improvements in step with the normal timing of investments to replace infrastructure and equipment as it wears out or becomes obsolete. Higher improvement rates are certainly possible if appropriate policies are in place to accelerate technological transformation of fossil fuel systems.

B. Environmental performance of fossil technologies

38. Emission reduction potentials are roughly proportional to efficiency improvements. The reduction potential is larger, however, when emissions controls are considered. For improved technologies that use the same fossil fuel, the efficiency gains translate to lower fuel costs, which can often offset the somewhat higher capital needs. Those technology improvements can result in significant secondary benefits, such as reductions of other pollutants (e.g., sulfur dioxide, nitrogen oxides and particulates). For example, emissions declined by some 24 per cent between 1990 and 1994 in western Europe and the economies in transition as a result

of continued sulfur reduction policies or economic recession and declines in coal use, respectively (Grübler, 1997). Conversely, emissions have increased in Asia significantly over the same time period, e.g., by about 22 per cent in China (Grübler, 1997).

39. Scenarios of future sulfur dioxide emissions foresee a fivefold increase in emissions in the highest case, while the lowest lead to reductions of a third of current levels. Taken together, the range of future sulfur emissions indicates a strong desulfurization of energy during the next century, partly due to shifts in the structure of the energy system away from sulfur-rich coals and partly due to overall energy efficiency improvements. Global carbon dioxide emissions projections can also be derived from the range of scenarios documented in the database developed by Morita and Lee (1997). They range from more than a tenfold increase to complete elimination of emissions altogether, which translates into an emissions range of more than 40 GtC by the year 2100 to no emissions at all, with a median of about 15 GtC. Both sulfur and carbon emissions are expected to decrease relative to economic and energy activities.

VIII. Suggestions for further action

40. Appropriate policies should be designed to support research, development and demonstration, and should be complemented by other measures for promoting efficient and clean energy that take into account the widely differing institutional, social, economic, technical and natural resource endowments in individual countries and regions. Such policies should include market instruments, such as subsidies, energy and emissions taxes, and regulatory measures, such as emission or fuel quality standards and codes, as well as voluntary agreements with industry.

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Notes

¹ In the 1990s, economic transition in the Republics of the former USSR and the East European countries resulted in significant declines in their energy consumption.

² Natural gas and electricity have the highest end-use efficiencies compared with the low primary to final conversion rates; the lowest end-use efficiencies can be observed for biomass, with 17 per cent at the global level and only 12 per cent in the economies in transition and the developing countries.

³ Energy intensities are different if GDP is estimated at market exchange rates rather than on the basis of purchasing power parities. Energy intensities of developing countries are substantially lower when economic activities are measured with purchasing power parities, which increases the value of economic activities since those countries have comparatively low price levels, thus reducing the magnitude of measured energy intensities.

⁴ In absolute terms, primary energy requirements are expected to range from a low of 7 Gtoe in the year 2100 (a decline compared to 1990 levels of 9 Gtoe) to almost 80 Gtoe in the year 2100. Most scenarios envisage consumption levels of between 14 and 32 Gtoe, or about 1.5 to 3.5 times 1990 consumption levels.

⁵ Fossil energy fuel cycles are the major source of air pollution in general. Both health and environment energy-related impacts can be identified with two main categories of underlying causes (World Energy Council, 1995a; International Institute for Applied Systems Analysis and World Energy Council, 1995). The first might be called "pollution from poverty"; it includes many categories of health risks, such as the high levels of indoor pollution, deforestation and high ambient concentrations of particulate matter in urban areas. The second category might be called "modern pollution"; its source is dense motorized traffic and electricity generation from low-grade coal, resulting in the high urban concentrations of air pollution.

⁶ First, it is essential to improve the conversion efficiencies of end-use devices, which would both conserve the limited availability of traditional sources of energy, such as fuelwood, and at the same time reduce air pollution. Second, and equally important, are the structural shifts away from traditional energy end-use patterns and energy forms towards more efficient modern conversion technologies and cleaner energy forms. Third, there needs to be a long-term shift towards energy services provided through clean, grid-dependent fuels.

⁷ Currently identified global fossil energy reserves are estimated at more than 1,000 Gtoe. That quantity is theoretically large enough to last more than 130 years at the current level of global energy consumption (9 Gtoe in 1990), or five times larger than total global fossil energy consumption since 1860 (Nakićenović et al., 1996). Coal accounts for more than half of all fossil reserves. Current estimates of fossil resources and additional occurrences are much larger but more uncertain than reserves. The global resources base is almost 4,000 Gtoe, with additional occurrences of more than 20,000 Gtoe, mostly in the form of gas hydrates. Thus, fossil energy is abundantly available in the world and known deposits are likely to last more than a century, and with technological and scientific progress in fossil energy extraction, many centuries again beyond that.

⁸ Examples of the efficiencies, total costs and carbon dioxide emissions for a number of representative end-use devices and their alternative fossil fuel cycles are assessed in the full report; examples include space and water heating, cogeneration, electric drives and refrigeration, lighting, automobiles, passenger aircraft and railways.



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Energy and sustainable development

Renewable sources of energy, with special emphasis on wind energy

Report of the Secretary General**

Contents

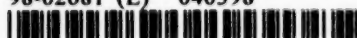
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* E/C.13/1998/1.

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I. Introduction

1. The present report summarizes the progress in wind energy to date and discusses the resource, technological, economic, environmental and sociological aspects of wind power today. It also summarizes the policy options available to stimulate the adoption of wind energy. An expanded version of the report contains brief case studies of five countries which accounted for 85 per cent of worldwide installed wind capacity in 1996, as well as recommendations with respect to critical policy options.¹

II. Wind energy resource potential

2. *Worldwide potential.* The International Energy Agency (IEA) has estimated the world's total demand for electricity to be 12,500 TWh in 1993 and 20,907 TWh by the year 2010. In comparison to this, the world's wind resources are abundant. Only few comprehensive investigations of the world's wind energy potential have been carried out to date, but they all conclude that the overall resource is much larger than the world's total electricity demand. However, wind potential is area-specific and geographically uneven. Nevertheless, the overall resource potential is vast, considering the potential in offshore locations, sparsely populated remote areas and complex terrain as well as the possibility of conjunctive use of land.

3. *Worldwide installed capacity.* Since 1980, modern grid-connected wind turbines have been installed in more than 50 countries around the world. As shown in table 1, early installations were predominantly in industrialized countries. Activity in developing countries has also picked up significantly in recent years, particularly in India and China. Egypt and Cape Verde, which are not included in table 1, have also experienced notable wind energy growth recently.

Wind power implementation scenarios

4. The World Energy Council (WEC), in "New renewable energy sources – a guide to the future" (1994), has prepared two global scenarios on wind energy penetration up to the year 2020: (i) the "Current policies" scenario, where the existing general economic and technological trends are assumed to continue; and (ii) the "Ecologically driven" scenario, which, compared with the "Current policies" scenario, assumes a faster development of wind turbine efficiency, imposition of a substantial carbon tax on fossil fuels and less severe financial constraints on the

development of wind energy. The overall results of the two scenarios are shown in table 2.

5. The two scenarios diverge substantially. The volume of wind-generated electricity is almost 2.5 times higher in the "Ecologically driven" scenario in 2020 than in the "Current policies" scenario. The relatively larger share of total worldwide kWh demand met through wind power in the "Ecologically driven" scenario is partly due to a projection of lower overall electricity use in this scenario. The penetration of wind power is assumed to start when the long-run marginal costs of conventional power become higher than those for wind power. Given this, wind penetration is assumed to be constrained primarily by financial resources and the growth of future wind turbine manufacturing capacity.

6. BTM Consult has recently evaluated the short-to-mid-term development of worldwide grid-connected wind power capacity. It projects the existing global installed capacity of 6.1 GW (1996) to increase to 17.5 GW by the year 2001 (a growth rate of almost 25 per cent a year) and to further increase to 33.5 GW in 2005, well in line with the 2010 WEC forecast in the "Current policies" scenario. In the short term, no capacity constraints in the manufacturing industry are foreseen; in fact strong competition between manufacturers is envisaged. Based on this study, global cumulative wind turbine capacity might reach roughly 375 GW in 2020, between the WEC "Current policies" and "Ecologically driven" estimates.

7. The above studies mainly concentrate on on-land siting of turbines. However, offshore applications are increasing, one in the Netherlands and two in Denmark. The latest Danish energy plan, Energy 21, projects the prospects for offshore turbines at more than 4,000 MW of installed capacity in Denmark before the year 2030.

8. Distinct markets exist for centralized grid-based systems and for decentralized remote communities which are off-grid. To date, the largest market has been in conventional centralized grid-connected applications. Decentralized (off-grid) systems have not been as common, since the off-grid communities are more difficult to access, often poor and often in developing countries, thus not providing commercially attractive markets. Small decentralized systems using wind energy may prove to be more cost-effective than extensions of the centralized transmission grid.

Table 1
Worldwide grid-connected wind capacity, in MW

	1991	1992	1993	1994	1995	1996
Europe						
Denmark	418	470	490	540	630	785
Germany	110	183	280	643	1 137	1 576
Greece	5	26	26	27	28	28
Italy	5	6	10	22	23	70
Netherlands	82	105	132	153	255	305
Spain	15	45	58	72	126	216
Sweden	8	12	24	40	67	105
United Kingdom	10	30	120	147	193	264
Other European	9	9	18	32	35	35
North America						
Canada	3	4	11	23	21	23
United States	1 575	1 584	1 590	1 725	1 770	1 794
Other North America	—	—	—	2	12	22
Asia						
China	—	—	13	25	36	57
India	39	51	80	120	550	820
Japan	2	4	5	5	10	14
Other	6	10	19	18	26	62
Total by end of year	2 287	2 539	2 876	3 594	4 905	6 172
Annual growth	285	252	337	718	1 311	1 267

Source: "Review of progress in the implementation of wind energy by the member countries of the IEA" (Paris, International Energy Agency/Organisation for Economic Cooperation and Development, July 1997).

Table 2
Wind capacity and wind-generated electricity in WEC scenarios

Scenario	Projected worldwide wind capacity: year 2005	Projected worldwide wind capacity and production: year 2020		Share of worldwide kWh demand: year 2020
	(GW)	(GW)	(TWh)	(Percentage)
"Current policies"	62	180	376	1.5
"Ecologically driven"	83	474	967	4.8

Source: "New renewable energy resources – a guide to the future" (London, World Energy Council, 1994).

Wind resource assessment and siting

9. Wind resource assessment usually refers to the calculation of average wind speed over 10 to 20 years at a specific site or area. Accurate determination of the daily, monthly and annual average wind speed is of paramount importance for the siting of wind projects. As a rule of thumb, the power output of wind turbines increases by the third power of the wind speed, and thus the cost of wind energy decreases drastically with increased wind speed. Current methodologies generally predict wind resources with good accuracy, but this is not the case for all sites. Therefore, users must understand the models' proper use and known limitations, and further research in some areas is necessary. Site-specific studies are also necessary for validating model results.

III. Technological status and trends

A. Modern wind turbine technology

10. Modern wind turbine technology can be classified in three main categories: large grid-connected turbines, intermediate-sized turbines in hybrid systems and small stand-alone systems. Large grid-connected wind turbines, in the size range of 150 kW to 2,000 kW, account for by far the biggest market value among wind turbines, and the technology for these machines is becoming mature. The size of commercially available grid-connected wind turbines has evolved from 50 kW in the early 1980s to the 500-800 kW range today. The next generation of commercial machines in the 1,000-1,500 kW size range have been installed as prototypes since 1995 and were commercially introduced into the market in 1997. Today grid-connected wind turbines are often placed in wind farms of 10 to 100 MW, which are operated as a single plant.

11. Intermediate-sized wind turbines in the 25-150 kW range can operate in hybrid energy systems combined with other energy sources such as photovoltaics, hydro, diesel and/or storage. Such systems are particularly well-suited for small remote grids where fossil fuel use is limited by transportation, environmental, cost or other constraints, and for special applications such as water pumping, battery charging or desalination.

12. Small "stand-alone" wind turbines of less than 25 kW are used for water pumping, battery charging and heating. Among small battery charging wind turbines, the 25-150 watt range (i.e., rotors of 0.5 to 1.5 metres) is by far the most commercially successful. Probably some 200,000 small

battery charging wind turbines for remote telecommunication stations are now in use. The main producers of small battery chargers are in the United Kingdom of Great Britain and Northern Ireland (marine and caravan leisure markets) and China (for semi-nomadic cattle raisers in the Mongolian region).

13. However, of the wind energy technologies currently in operation, the mechanical farm windpump remains the most numerous. One to two million units are in regular use worldwide, with over 50 known manufacturers active in this field. The main application for mechanical farm windpumps is for drinking water supply in rural areas. The present annual installation of windpumps is estimated at 5,000 to 10,000 units.

B. Recent technological developments

14. Two general types of wind turbines exist, named after the direction of their main shaft: horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT). VAWT machines have not lived up to their early promise and, today, only a very small fraction of wind turbines in operation are of the VAWT type. Hence, the present report focuses solely on the HAWT type.

15. Average turbine size has increased drastically over the past 15 years, and there are only a few technical barriers to further up-scaling of size, including transportation and availability of large cranes near the site. Electricity production efficiency is also rapidly improving, owing to higher towers, larger rotors and better aerodynamic performance. This increased size and efficiency lead directly to increased annual energy output per square metre of land occupied, which is important in regions with limited land availability.

16. The prime objective for industrial R&D in wind turbine technology is cost reduction. The cost of wind turbines and consequently, power production costs, have decreased steadily since the beginning of the 1980s. Wind turbine technology's progress ratio (i.e., the decline in costs each time the cumulative volume doubles) has been of the order of 15 per cent. This development is expected to continue in the future, perhaps at a slightly slower pace. Wind turbine noise emissions have also been lowered owing to better designed blades, improved manufacturing quality of mechanical parts and use of damper materials.

C. Wind turbine influence on the electricity grid

17. *Capacity credit.* The capacity credit of wind power can be determined by use of the "loss-of-load-probability" (LOLP), a measure of power availability commonly used by power utilities in planning the expansion of power generation capacity. Using the LOLP approach, at small wind energy penetration levels (up to 10 per cent of total kWh production) the capacity credit of many widely dispersed wind turbines in a large grid is approximately equal to the turbines' capacity factor, which is typically in the range of 20 per cent to 40 per cent. Even at higher wind energy penetration levels, the capacity credit of wind power can still be substantial. Cape Verde achieved a capacity credit of 75 per cent of the wind turbines' capacity factor at 25 per cent to 50 per cent wind energy penetration.

18. *Short-term prediction.* Based on general weather forecasting models and the wind speed at a site or in a region, power production from the wind turbines in a power utility's area can be predicted with good accuracy. Using such forecasting models, the power utility's dispatcher can obtain the predicted power production from wind turbines over the next 36 hours on a computer screen, thus minimizing dispatch difficulties. Such predictive tools can also help in determining the potential for peak load management in a grid system, in terms of wind power availability during peak load periods.

19. *Power quality.* Although concern has been expressed over wind energy's potential impact on power quality (e.g., real time power demand, voltage level, voltage flicker, harmonics, frequency variations), these can be resolved effectively through technical, operational and management measures.

IV. Economics of wind energy

20. The present section focuses on the economics of grid-connected wind turbines only, as they account for the bulk of the market value of installed turbines. The main parameters governing wind power economics are: (i) investment costs, including auxiliary costs for foundation, grid connection, and so forth; (ii) operation and maintenance costs; (iii) electricity production/average wind speed; (iv) turbine lifetime; and (v) discount rate. Of these the most important are the turbines' production of electricity and the investment costs. As electricity production is highly dependent on wind conditions, choosing the right turbine site is critical to the economic results.

A. Capital cost and efficiency trends

21. In general, two trends have dominated grid-connected wind turbine development: (i) the average size of turbines sold on the market has increased substantially; and (ii) the efficiency of production has increased steadily. The average size of turbines sold in the Danish export market has increased from roughly 50 kW in 1985 to over 500 kW in 1996. Currently, the best-selling turbine has a rated capacity of 600 kW, but turbines are now sold with capacities as high as 1,500 kW. Moreover, electricity production efficiency, measured as annual energy production per swept rotor area (kWh/m^2) has increased by more than 5 per cent annually over the past 15 years.

22. Capital costs of wind energy projects are dominated by the cost of the wind turbine itself (ex-works). For a typical 600 kW turbine in Denmark, the turbine's share of total cost is approximately 80 per cent, while grid-connection accounts for approximately 9 per cent and foundation for approximately 4 per cent. Other cost components, such as control systems and land, account for only minor shares of total costs.

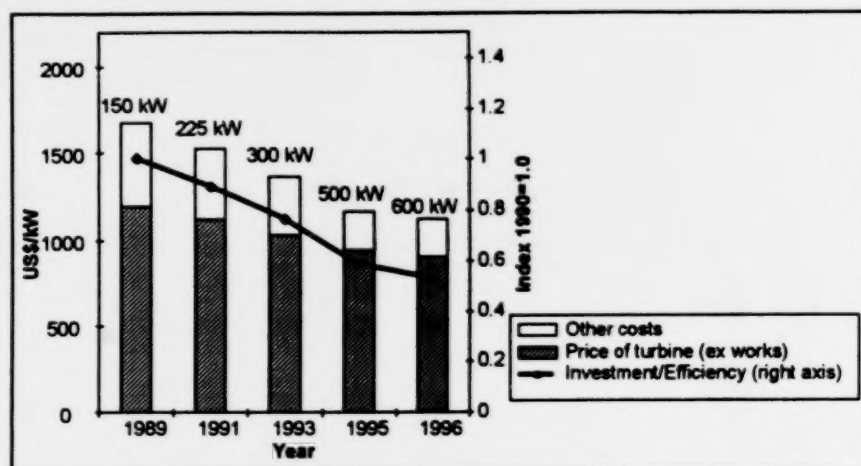
23. As shown in figure I, there has been a substantial decline in per-kW costs, turbine costs (4 per cent per year) and auxiliary costs. Thus, the general investment costs per kW declined by more than 5 per cent a year from 1989 to 1996. Combining the efficiency improvement and the decline in investment costs per capacity unit implies that the total investment per annual production ratio has improved by more than 45 per cent since 1989, or more than 8 per cent a year in real terms, also shown in figure I (right ordinate).

24. Wind energy project capital costs as reported by the International Energy Agency show substantial variation between countries, due to factors such as market structures, site characteristics and planning regulations: total wind project capital costs vary between approximately US\$ 900 per kW and US\$ 1,600 per kW in different countries.

B. Operation and maintenance costs

25. Operation and maintenance (O&M) costs constitute a sizeable share of total annual costs for the turbine. Only a limited number of turbines have existed for the full expected lifetime of 20 years. For this reason estimates of O&M costs are highly uncertain, especially in the later years. O&M costs are primarily influenced by turbine age, starting low and increasing over time. For a 150 kW turbine, annual O&M costs are estimated at approximately 1.2 per

Figure I
Wind turbine capital costs (ex-works) and other costs
(US\$/kW in constant 1996 dollars)



Source: *Privatejede Vindmøllers Økonomi* (The Economics of Privately Owned Wind Turbines) (Danish Energy Agency, 1994) and P. Nielsen, Energy and Environmental Data, 1997.

cent a year of capital investment cost during the first two years of turbine life, rising to 7 per cent a year in years 16-20. For a 600 kW turbine, the corresponding O&M costs are approximately 1 per cent a year during the first two years, rising to 4.5 per cent a year in years 16-20.

C. Overall cost-effectiveness

26. The total cost per produced kWh (unit cost) is calculated by levelizing investment and O&M costs over the lifetime of the turbine, divided by the annual electricity production. The unit cost of generation is thus calculated as an average cost. In reality, actual costs will be lower than the calculated average at the beginning of the turbine's life (owing to low O&M costs) and will increase over the period of turbine use. Figure II shows the calculated unit cost for different sizes of turbines based on the above-mentioned investment and O&M costs, a 20 year lifetime and a discount rate of 5 per cent a year (in real terms). The turbines' electricity production is estimated for roughness classes one and two, corresponding to an average wind speed of approximately 6.9 metres per second (m/s) and 6.3 m/s, respectively, at a height of 50 metres above ground level. Figure II illustrates the trend towards larger turbines and greater cost-effectiveness. For a roughness class one site (6.9 m/s), for example, the average cost in 1996 United States dollars has decreased from approximately 8.8 cents per kWh

for the 95 kW turbine to approximately 5 cents per kWh for a new 600 kW machine, an improvement of almost 45 per cent over a time span of 9-10 years.

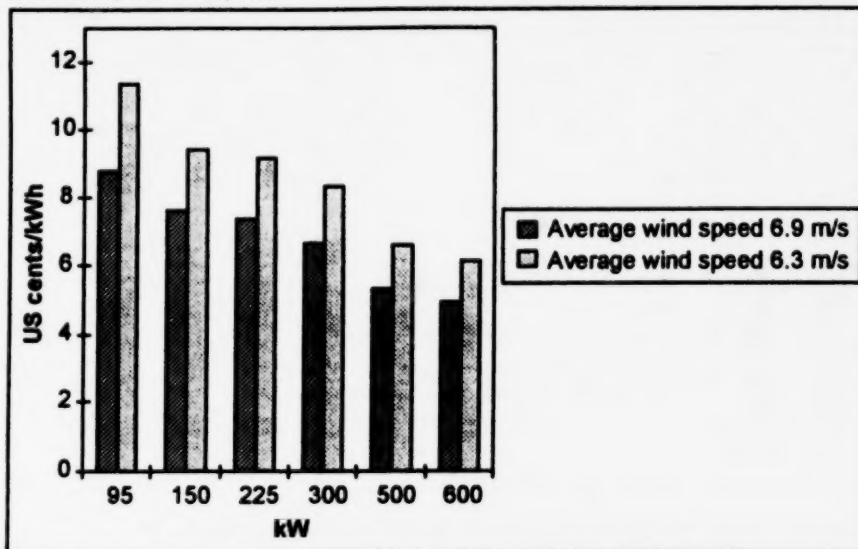
27. The discount rate has a significant influence on production costs and hence on the financial viability of wind projects. For a 600 kW turbine, changing the discount rate from 5 per cent to 10 per cent a year (in real terms) increases the production cost by a little more than 30 per cent, from 5 United States cents per kWh to 6.7 United States cents per kWh. In project-financed wind projects in the United States of America, for example, nominal discount rates for projects financed with 50 per cent debt – 50 per cent equity has been over 12 per cent a year, thus significantly raising project costs.

D. Comparison with the cost of conventional power

28. The cost of conventional electricity production is determined by three components: (i) fuel cost; (ii) operation and maintenance costs; and (iii) capital cost. When wind is substituted for conventional methods of generating electricity, the avoided cost depends on the consideration of each of the three components. It is generally accepted that implementing wind power avoids the full fuel cost and a considerable portion of the O&M costs of the displaced

Figure II

Total turbine costs per unit of electricity produced, based on a hub height of 50 metres
(US cents/kWh, constant 1996 prices)



Source: R. Redlinger and others, Risø National Laboratory Denmark.

conventional power plant. The level of avoided capital costs depends on the extent to which wind power capacity can displace investments in new conventional power plants and is thus directly tied to the capacity credit of wind plants. The capacity credit will depend on a number of different factors, for example the level of penetration of wind power and how the wind capacity is integrated into the overall energy system. In general, for marginal levels of wind penetration, the capacity credit for wind turbines is close to the annual average capacity factor. Thus, 25 per cent is considered a reasonable capacity credit for wind power when the volume of wind-generated electricity is less than 10 per cent of total electricity production. This capacity credit declines as the proportion of wind power in the conventional system increases; but even at high penetrations a sizeable capacity credit is still achievable, as discussed in section III.

29. Costs avoidable through wind electricity are shown in figure III, assuming that all fuel and O&M costs are avoided and that wind power is assigned a very conservative capacity credit of 0 per cent. For example, for Germany, for each kWh of electricity generated by wind power which displaces a kWh of coal power, approximately 7 United States cents per kWh are avoided in coal fuel and O&M costs, even if the wind plant receives no credit for displacing any coal plant capital costs. The estimated costs for a 600 kW on-land turbine at average sites in Denmark and the United Kingdom

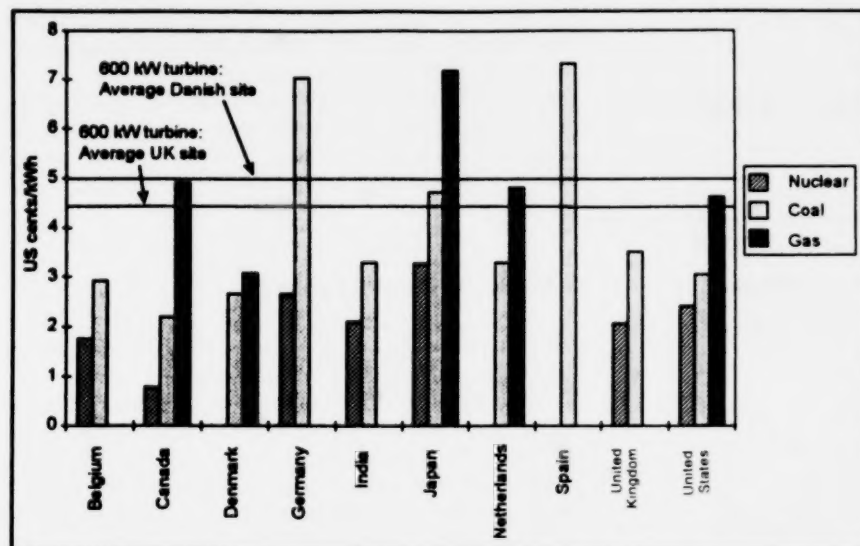
are also shown (5 United States cents and 4.5 United States cents per kWh, respectively). Therefore, if a wind turbine could be installed in Germany at an average cost of 5 United States cents per kWh and thus displace coal-generated electricity costing 7 United States cents per kWh, then a net 2 United States cents per kWh would be saved on every kWh of electricity generated by wind.

30. The 600 kW turbine is thus competitive, or nearly so, in terms of direct costs in a number of countries, especially in relation to technologies based on coal and gas. Such comparisons are conservative, as they assume no capacity credit for wind energy, making it difficult for wind energy to compete. Assuming a more realistic capacity credit for wind, such as 25 per cent, would raise the avoided costs and thus further improve wind's competitiveness, particularly in comparison with nuclear energy, whose costs are dominated by capital costs. Moreover, the environmental benefits of wind energy, for example in relation to acidification and global warming, are not included in the figure.

31. Figure III would change significantly if a higher capacity credit for wind were assumed. For example, for the United States, figure III shows avoided costs of 2.41, 3.04 and 4.62 United States cents per kWh for nuclear, coal and gas, respectively, assuming a wind capacity credit of zero. If the wind capacity credit were raised to 25 per cent, the

Figure III

Avoided costs of conventional power, excluding capacity credit, compared with production costs for wind-generated electricity
(1996 US cents/kWh)



Source: Based on the cost data from, "Projected costs of generating electricity" (Paris, IEA/OECD, 1993)

avoided costs would change to 3.00, 3.52 and 4.76 cents per kWh and at 50 per cent capacity credit, they become 3.59, 4.00 and 4.89 cents per kWh. This highlights the importance of capacity reliability and dispatchability, but this importance may change in the future as spot markets and financial options develop in competitive electricity systems to better handle power variability.

E. Economics of small-scale irrigation pumping

32. Large-scale electric applications have seen the most notable advances in wind energy in recent years and are the focus of the present report. Nevertheless, the most common type of wind energy application, in terms of number of installed units, remains the small-scale mechanical wind pump for irrigation water pumping. Such wind pumps are widely used in both developed and developing countries and can be particularly attractive when electric grid access is not readily available. In one study, which compared wind pumps with kerosene pump sets, diesel pump sets, solar PV systems, or solar rankine pump systems in various countries, wind pumps were found to be far more cost-effective than

solar systems and in most cases they were also cheaper than kerosene and diesel pump sets. Financial cost-effectiveness is significantly influenced by subsidies, which are often available on kerosene or diesel; and the high capital cost of wind systems compared with kerosene or diesel sets makes the financial performance of wind pumps sensitive to prevailing interest rates.

V. Environmental and social considerations

A. Environmental impacts

33. The 1995 ExternE, "Externalities of Energy", study conducted by the European Commission represents one of the most comprehensive efforts to date to quantify monetary values of environmental externalities for a wide range of fuel cycles: coal, nuclear, oil, gas, hydro and wind. The study characterizes the wind energy fuel cycle as including the following environmental impacts: noise, visual amenity, global warming, acidification, public accidents, occupational accidents, land use, bird mortality and radio interference. Construction and installation of the wind turbines involve

energy use, which creates air emission impacts, though this depends on the nature of the energy resources in use at the time of construction. Based on two wind farm sites in the United Kingdom, the ExternE study quantified the externalities of wind energy as shown in table 3.

Table 3
Environmental externality values of wind-generated electricity

Category	External costs (mECU/kWh) ^a
Noise	0.07-1.1
Visual amenity	Not quantified
Global warming	0.15
Acidification	0.7
Public accidents	0.09
Occupational accidents	0.26

Source:
ExternE, "Externalities of Energy" study (European Commission, 1995).

^a Mills of a European Currency Unit per kilowatt hour.

34. Noise values showed a wide variation depending on the population density surrounding the site. The study did not place a specific value on the visual amenity but estimated it to be very small outside of recreationally important designated scenic areas, and most likely well below 1.9 mECU/kWh. If one were to assume a median noise value of 0.6 mECU/kWh and a visual amenity value of 1.0 mECU/kWh, then summing the identified values in table 3 would result in a total environmental externality value for wind energy of 3 mECU/kWh (US\$ 0.0038/kWh). Bird mortality impacts were estimated to be negligible in the United Kingdom (though perhaps higher in other locations including the United States), as were land use impacts owing to the very small land area used by the turbines themselves and their compatibility with both agriculture and animal life. While the total wind externality value is not trivial, it is considerably less than the electricity generating cost, especially because the global warming and acidification impacts are secondary impacts, stemming from an assumption of fossil-fuel-based primary energy use for turbine manufacturing. Excluding such secondary emissions (which were excluded by ExternE for all other fuel cycles) would lower the wind externality value to approximately 2 mECU/kWh (US\$ 0.0025/kWh).

35. Comparisons with other fuels are difficult owing to differences in assumptions and methodologies. However, based on other ExternE fuel cycle studies, figure IV provides highly approximate externality estimates for the other fuel cycles in comparison with wind, in United States dollars. The possible ranges on these values are very large, and all numbers should be used only with extreme caution. Nevertheless, wind energy's environmental impacts appear to be no higher than those of any other fuel and considerably lower than those of fossil fuels. In addition, wind energy's environmental impacts are local, relatively predictable and primarily aesthetic.

B. Social considerations

36. As discussed above, visual and noise impacts are considered the most negative consequences of wind power. Because these impacts are entirely local in nature, they can cause significant local planning and siting concerns. It may be noted, however, that the noise from a wind farm at a distance of 350 metres is of the order of 45 decibels (approximately the same as that from a car travelling at 40 miles an hour at a distance of 100 metres) and as such the noise is less than the daytime rural background noise levels and is only slightly greater than the night-time levels.

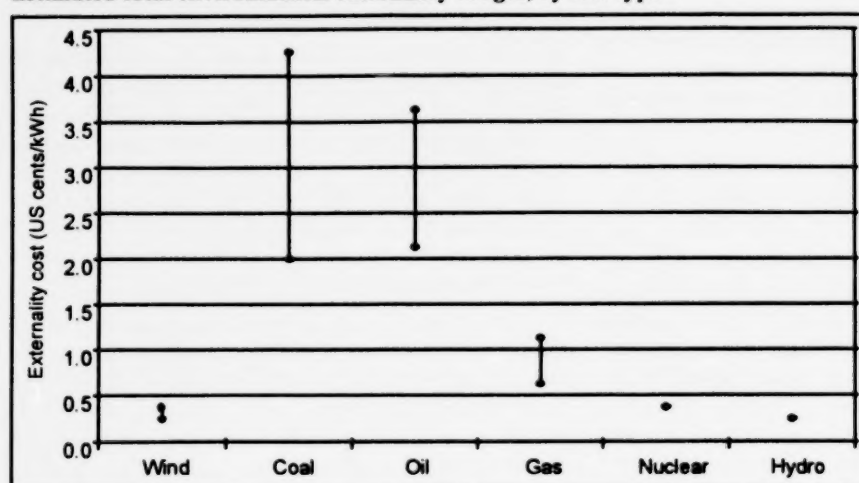
37. Job creation is another social consideration of great interest. Worldwide, employment in the wind energy industry is currently estimated to be approximately 30,000 to 35,000 jobs for supplying 1,200 MW of new installed wind capacity a year. In developing countries, the employment and balance of payments implications of modern high-technology wind turbines are less clear, as they will continue to require the import of equipment (though not fuel) and perhaps specialized labour.

VI. Incentive mechanisms to promote wind energy development

38. A variety of incentive mechanisms have been used to promote the development of wind energy projects and have led to the generation of considerable modern wind energy in a number of OECD countries and some developing countries. A number of these are described below.

39. *Power purchase agreements (PPA)*. Perhaps the single most critical requirement of a successful wind energy project is a reliable market for selling the electricity produced. In a vertically integrated monopoly utility system, a utility which chooses to build wind power plants would of course

Figure IV
Estimated total environmental externality ranges, by fuel type



Source: ExternE, "Externalities of Energy" study (European Commission, 1995).

have a guaranteed market. However, much of wind power development has been carried out by independent power producers unaffiliated with any utility. In this case, a mechanism is necessary, by which the wind developer can sell its generated electricity to the utility. Creation of stable markets has thus been a prime objective of establishing PPAs.

40. *Production subsidy.* Where electricity generated by wind is more costly than that generated by conventional sources, wind energy may not be economically attractive at the going electricity rate. In that case, a production subsidy, paid per kWh of electricity generated, can lower the cost of wind energy and make projects economically viable. The subsidy would typically be paid either by the Government out of the general tax base or by utility customers through a surcharge on their utility bills. Such subsidies are meant to be time-limited and phased out over time as technological development makes wind energy fully competitive in the marketplace.

41. *Tax credits.* Tax credits can be provided based either on the capital cost of the project or on the kWh generated by the project. Tax credits based on capital cost are preferred by investors because the tax credit can be claimed regardless of the project's performance in actually generating electricity. For highly risky projects, investors might be willing to provide finance only under such generous conditions. On the other hand, tax credits based on the capital cost can be subject to abuse because investors simply interested in a tax shelter have little incentive to ensure that

their projects actually produce electricity. Production tax credits, paid per kWh of electricity generated, reduce the scope for abuse by making payment contingent on project performance, thus increasing the risk to project investors.

42. *Renewables set-aside.* A renewables set-aside mandates that a certain percentage of total electricity generated must come from renewable sources. In some cases, this percentage can be further broken down into separate allocations for different technologies, such as wind, solar, biomass and the like. A set-aside policy thus creates a guaranteed market for electricity generated by renewable energy technologies which might not otherwise be able to compete in the prevailing generation market.

43. *Externality adders.* As traditional energy planning has largely ignored the environmental externalities of power production, some regulators have attempted to address this issue by increasing the hypothetical cost of conventional power plants through an environmental externality charge or "adder" in the planning stage. Such adders can improve the likelihood of wind energy plants being built by increasing the apparent cost of conventional technologies. Typically, externality adders are included only in the planning stage for resource selection but are not actually charged on operations, thus not affecting power plant dispatch once projects are built.

44. *Carbon tax.* Like the externality adder, the carbon tax adds to the cost of fossil-fuel-based energy by imposing a per-kWh tax on the basis of the carbon content of fuels and

their likely impact on global climate change. Carbon-free energy sources like wind energy can thus become considerably more competitive against fossil fuels because of such a tax. Unlike the externality adder, however, the carbon tax involves actual payment of money and is not merely a hypothetical charge used for planning purposes only.

45. *Preferential finance* covers concessional loans at below-market interest rates, official co-financing to attract commercial lenders, loan guarantees and the like.

46. *Research, development and demonstration grants.* Several Governments provide or have provided research, development and demonstration (RD&D) grants for wind turbine technologies as well as for resource assessment, environmental considerations and other related areas. According to the International Energy Agency, the United States had the largest wind R&D programme in 1996, followed by Japan, the Netherlands, Denmark and Italy. Total wind energy research and development funding by OECD Governments amounted to approximately US\$ 70 million in 1996. Caution must be exercised in making cross-country comparisons owing to countries' different accounting systems. In addition, high RD&D spending does not in itself lead to wind energy success. Between 1973 and 1988, the United States and Germany spent roughly US\$ 380 million and US\$ 79 million, respectively, on wind RD&D, but Denmark came to dominate the world turbine manufacturing market, spending only US\$ 15 million on RD&D during the same period. Successful RD&D spending must be carefully integrated with reliable long-term markets for wind-generated electricity.

VII. Recommendations

47. Designing appropriate policies in developing countries can benefit from experience gained in the use of the incentive mechanisms mentioned in section VI. Their practical application will, however, require strengthening the institutional capacity of policy and regulatory bodies. This is of particular importance for countries embarking on the privatization of public sector utilities. Key elements of a policy aimed at promoting renewable energy sources may well include many of the following.

48. *Establishment of rational pricing and well-designed incentive mechanism.* Price reforms in the conventional electricity sector may be necessary in many countries. Excessively subsidized conventional electricity would otherwise constitute a significant barrier to renewables. In

addition, incentive mechanisms based on those described above should be tailored to the specific circumstances of developing countries.

49. *Provision of stable markets for wind-generated electricity.* Reliable markets for wind-generated electricity are the single most important factor for stimulating the further development of wind energy. Stable power purchase contracts have been a critical feature of the energy policies of all countries that have achieved wind energy success. Since a state of full and complete competitiveness has not yet been reached, some level of additional support will remain necessary for the next several years.

50. *Provision of stable wind turbine markets.* Countries should also encourage stability in markets for new wind turbines to ensure the industry's viability and stimulate technological development. It is not necessary for this market to be large, as market reliability is a much more important feature than market size.

51. *Alignment of energy projects' financial performance with society's environmental goals.* Efforts should be redoubled to introduce appropriate mechanisms that will better align energy projects' financial performance with society's environmental goals.

52. *Enhancement of community participation in project planning and in reaping project benefits.* The visual and noise impacts, while low, are nevertheless real and must be addressed through an open and straightforward planning process. Opposition is also considerably reduced when local residents are well informed and are able to profit financially from wind energy projects in their communities.

53. *Encouragement of decentralized projects in remote communities.* Wind energy can be highly cost-effective in remote communities not served by a central electricity transmission grid. However, as such communities are often poor and in developing countries, less effort has been made to address these markets; and the bulk of wind energy development has occurred in the context of centralized grid-based generation. Additional efforts should be directed towards making financing available and stimulating off-grid wind energy projects in remote communities, particularly in the context of rural electrification programmes in developing countries.

54. *Removal of institutional barriers to wind energy.* Stable professional communities should be developed that understand wind energy issues and can facilitate their countries' long-term wind energy development. Development of institutional capacity also includes information dissemination, development of appropriate

planning processes, suitable certification arrangements for turbines and perhaps wind energy demonstration programmes where no projects yet exist.

55. *Encouragement of research and development, particularly for wind resource assessment.* Technology development is already successfully addressed by the private sector and may not require significant public funding. However, public assistance would be required for accurate wind mapping to identify suitable sites for wind energy electricity generation. In developing countries, particularly least developed countries, dissemination of these technologies will nonetheless require extensive international cooperation.

Notes

- ¹ The present report was prepared on behalf of the Department of Economic and Social Affairs of the United Nations Secretariat by Robert Y. Redlinger, UNEP Collaborating Centre on Energy and Environment, Per Dannemand Andersen, Wind Energy and Atmospheric Physics Department and Poul Erik Morthorst, Systems Analysis Department, all located at Risø National Laboratory, Denmark. It is based on an extensive study by the same authors commissioned by the Secretariat. Funding for the study was provided by the Ministry of Foreign Affairs of Denmark, and is gratefully acknowledged.
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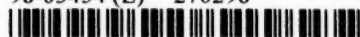
Energy and sustainable development

Development and implementation of rural energy policies**Report of the Secretary-General***Summary*

The provision of energy services to rural areas remains inadequate owing to the dispersed nature of the population and the low income levels of rural dwellers. Of the estimated 3.1 billion people in rural areas, approximately 2 billion have no access to electricity and about the same number of people rely on traditional energy sources for cooking, such as wood, charcoal and animal and plant wastes, which are associated with adverse environmental effects at the local level.

Policies aimed at providing modern energy services to rural areas in many countries have focused on extending national electricity grids to rural areas. Although these policies have been successful in many areas, they have often necessitated substantial subsidies to customers in remote areas with low population densities since the unit cost of supply is higher. These subsidies have resulted in a precarious financial position for some electricity generating companies, many of which are nationally owned. Moreover, the companies themselves often rely on national budgetary allocations for the capital cost of expanding the grid since their revenues (inclusive of subsidies) are inadequate to service finance available from private financial markets. Thus many rural areas have no access to a national grid and, even in areas which do have access, many rural dwellers are not connected. In addition, low electricity prices, along with subsidies for other conventional fuels, may have discouraged the adoption of renewable energy technologies.

* E/C.13/1998/1.



Renewable energy technologies often have cost advantages for rural areas since transportation and/or transmission costs are not a significant portion of total costs, but they may require periodic maintenance to operate efficiently. Their successful adoption in rural areas can aid in providing modern energy services with fewer adverse environmental consequences than energy services produced from conventional fuels. Recent technical advances have lowered the cost of some, and many countries are investigating the possibility of encouraging small decentralized systems to serve isolated rural areas.

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I. Introduction

1. The present report has been prepared in response to the request of the Committee on New and Renewable Sources of Energy and on Energy for Development at its second session (12-23 February 1996),¹ which was approved by the Economic and Social Council in its decision 1996/304.

2. Efforts at finding the most appropriate solution for rural area energy problems are hampered by insufficient attention to rural development in general and to rural energy needs in particular. The lack of institutional support is partly due to the fact that rural energy is a small component of the total energy used in a typical developing country and often is not even included in energy statistics and balances since much of it is non-commercial and thus not traded. With no government agency taking primary responsibility for rural energy needs, few resources have been devoted to data collection and assessment, which are important steps in developing rural energy policies, or to the promotion of suitable energy projects specifically for rural areas. Agricultural policies have often failed to recognize that the availability of adequate energy supplies can result in increased agricultural production, related increases in agro-industrial production and better market access.

II. Rural energy demand and supply

A. Demand for energy in rural areas and benefits from increasing use

3. Effective demand for energy in rural areas of many developing countries is constrained by low-income levels. Although used mainly by households for cooking purposes, energy is also used in agriculture for water pumping and irrigation. Households in rural areas are dependent on non-commercial sources of energy, such as firewood and other fuels, and their choice of fuel is often determined by energy availability in the area. Charcoal is also used in rural as well as urban areas for cooking. The production, distribution and sale of charcoal has become a small-scale industry in many rural and urban areas, which supports a large number of low-income people in developing countries.

4. As income increases, the type of energy used by rural households changes. In areas where annual per capita income is less than \$300, 90 per cent of the people use traditional fuels for cooking.² As incomes increase above that level, to between \$1,000 and \$1,500 a year, households tend to rely entirely on conventional fuels.

5. Rural energy demand increases with population growth, which is slowing. Rural population in developing countries is put at 2.8 billion and average annual population growth has slowed, declining from 1.39 per cent during the period 1975-1980 to 0.86 during the period 1990-1995. Rural population growth is expected to decrease to 0.51 per cent a year during the period 2000-2005 and continue falling to 0.22 per cent during the period 2010-2015.³

6. Energy is used in agriculture in developing countries to pump water, irrigate crops, operate machinery and process and preserve food. Increasing energy use raises yields and improves quality. The availability of cheap dependable motors and pumps, as well as the increasing availability of fuel and/or electricity, has enabled more land to be irrigated in many countries, especially in areas unsuitable for irrigation by gravity flow techniques. In some regions, however, the proportion of irrigated land is low. In sub-Saharan Africa only 4 per cent of arable land has been irrigated; in Latin America 15 per cent is under irrigation while in Asia irrigated land is 38 per cent of total arable land. In order to provide food for a growing population, irrigated land will have to increase in the future and will result in an increased demand for energy for agricultural uses.⁴

7. As developing countries implement economic and social policies aimed at promoting rural development, commercial and light industry use of energy is expected to increase. Some rural areas may see a rise in agricultural-related industries such as food processing, while small-scale industries are likely to be a characteristic of much of the growth and development in many rural areas in which development policies are successful.

8. Increased use of energy in rural areas for cooking allows for a more varied diet. Energy available for heating improves the quality of life for rural dwellers in colder climates. Lighting in rural areas not only provides benefits to households but to health-care clinics, where refrigeration is important, and for water pumping as well. Increased energy availability facilitates the increase of rural incomes and the reduction of poverty. Switching from the use of traditional sources of energy to modern energy sources or to renewable sources can significantly improve the health of rural dwellers. The burning of firewood and dung emits particulate matter, carbon monoxide and other pollutants which are responsible for a variety of health problems, including chronic bronchitis, emphysema and other respiratory diseases, which contribute to higher mortality rates. Infants and children are also adversely affected as acute respiratory infections, which cause approximately 4 million deaths each year, are at least partially attributable

to smoke inhalation.⁵ The table shows the estimated exposure to pollutants from cooking one meal with various types of stoves.

Estimated exposure to respirable particulates (RSP), carbon monoxide (CO), nitrogen oxide (NOx) and formaldehyde (HCHO) resulting from cooking one meal on an unvented stove
(milligrams)

Type of stove	RSP	CO	NOx	HCHO
Wood fired	17.0	340.0	8.5	0.69
Kerosene	4.2	58.0	1.5	0.069
Gas	0.012	5.9	0.27	0.05

Source: E. W. Cecelski, "From Rio to Beijing - engendering the energy debate", *Energy Policy*, vol. 23, No. 6 (June 1995), p. 566.

9. The burden of gathering fuelwood from distant locations and the health consequences of burning traditional fuel fall largely on rural women, who are responsible for gathering wood and for cooking. In rural Kenya, for example, some women spend 20 to 24 hours a week collecting branches, cow dung and crop residues to use as fuel. Moreover, as men have migrated to urban areas in search of employment, additional agricultural work has been increasingly borne by women. Switching to modern fuels or to non-traditional renewable energy sources improves the quality of life for all rural dwellers, but especially for women in terms of more productive use of their time and improved health.

10. When the demand for traditional energy sources exceeds sustainable yields, forested areas shrink and brushwood and vegetation areas become seriously degraded, ultimately reducing soil fertility and, in some areas, accelerating desertification. It is estimated that 130 million people in sub-Saharan Africa live in areas where fuelwood consumption outpaces the natural regenerative capacity of the forest.⁶ Even in places where the problem has not yet reached a critical level, reduced vegetation results in lower soil fertility and diminished crop yields.

11. Variations in climate and local environmental conditions cause differences in consumption patterns between regions, and even within regions, which complicates policy design. The availability of energy within an area often determines which type of traditional fuel is used. China provides an interesting example of the variations seen in rural energy demand by region. Climate conditions

vary widely in different regions of the country, with climate zones ranging from temperate to subtropical with a monsoon climate. Northern areas face colder conditions in the winter. Households in rural areas consume energy for cooking, for heating, for electrical appliances (where available) and for transport. Per capita energy use in rural areas varies from 3.6 kgce (kilograms of coal equivalent) to 295.9 kgce, depending in part on geographical conditions.⁷ Income variations by area and differences in economic development patterns are also factors affecting rural energy demand. Moreover, the type of energy used depends on the local availability of fuel and its cost. In some areas, small coal mines are in use and raw coal is very inexpensive or even free for miners. Electricity is not available in all rural areas but its availability affects the type of energy used. Other non-commercial energy sources, including firewood, animal wastes, bagasse, crop residues and charcoal, are also used in rural areas of China according to accessibility. While China is not typical in this regard, wide variations in the pattern and level of energy demand can be found within countries as well as within regions.

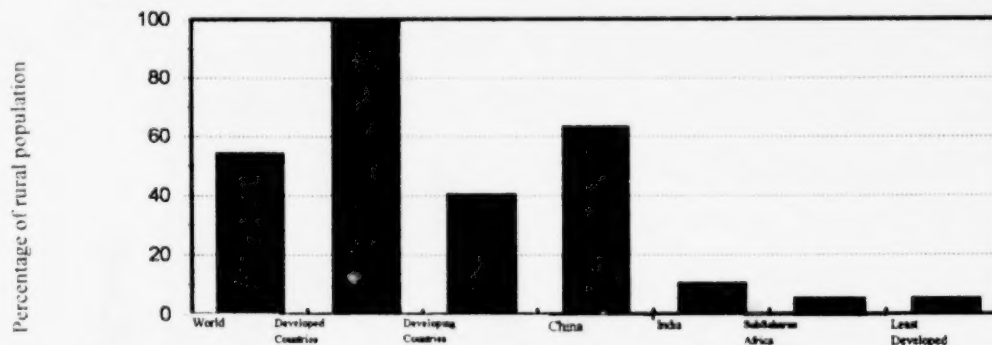
B. Supply of energy in rural areas

12. Energy in rural areas can be supplied from more diverse sources than in urban areas since conventional commercial sources of energy, traditional sources and a combination of renewable energy technologies may all be cost effective in rural areas, depending on the circumstances.

1. Conventional sources of energy

13. Electricity produced by hydroelectric facilities as well as from coal, oil and natural gas has become available in many rural areas as a result of rural electrification programmes undertaken in many developing countries. Petroleum is used for transport and diesel oil for producing electricity with the use of small electric generators, as well as for transport, while liquefied petroleum gas (LPG) and kerosene are often used for heating and cooking.

14. Many developing countries have made rural electrification a priority and, as a result, 820 million rural dwellers in developing countries have access to electricity.⁸ Since this figure includes 500 million people who were provided access to electricity in the 20-year period from 1970 to 1990, the improvement has been considerable, although many rural dwellers still do not have access to electricity. Figure 1 shows the percentage of rural population with access to electricity grid services, which in some rural

Figure 1. Percentage of rural population with access to electricity

Source: Based on data and estimates for 1990, in K.-N. Mak and W. Shearer, "Sustainable energy development in rural Asia", *Natural Resources Forum*, vol. 20, No. 4 (November 1996), p. 294.

Note: Recent data indicate a higher level of rural electrification in India.

areas is quite low. There is also significant variation by region, from less than 10 per cent in sub-Saharan Africa to an estimated 45 per cent in the East Asia and the Pacific region.⁹ Forty per cent of rural dwellers in the Latin America and Caribbean region are connected to electricity while estimates are put at 35 per cent for North Africa and the Middle East and 25 per cent for South Asia.

2. Traditional sources of energy

15. Since traditional fuels are usually not counted in energy statistics, they are often overlooked by planners and policy makers and their supply is difficult to quantify and analyse. Thus, actual energy supply in rural areas is often higher than captured in official statistics. Regional characteristics may affect the type of traditional energy supply, but generally firewood, charcoal, biomass and animal waste are the sources of energy used in rural areas, usually by the poorest people. These sources are inefficient compared with modern fuels and often costly, whether in cash or in terms of labour time spent gathering fuel from rural areas. As shown in figure II, traditional fuels are characterized by low efficiency.

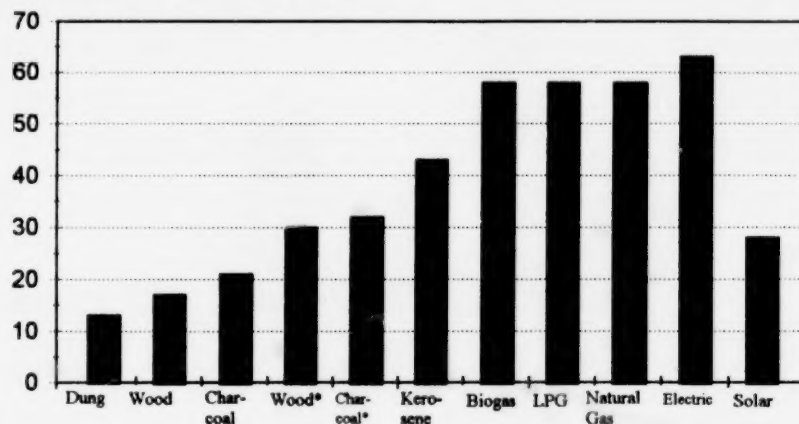
16. Firewood and charcoal are both commercially traded and non-traded sources of energy and are available in both rural and urban areas. The supply to urban areas of commercially traded firewood and charcoal has contributed to the growing shortage of fuelwood in many rural areas. Considerable environmental degradation has resulted from the overuse of wood fuels.

17. A number of renewable energy technologies may be cost-effective in rural areas. The decentralized systems with the most potential for rural areas are minihydropower systems, solar systems, wind energy, modern biomass, including biogas, and geothermal systems.

3. Renewable energy technologies

18. *Mini (and micro) hydroelectric.* Minihydroelectric installations generally produce less than 1 megawatt (MW) and usually do not need large expensive dams for water storage. They are cost-effective with few environmental externalities. However, their suitability depends on the topology of the area and they may not provide year-round service. Access to credit is often needed for such projects in rural areas. In addition, their construction and maintenance require technical expertise often not available in those areas.

19. *Solar systems.* Solar systems are divided into photovoltaic (PV) and solar thermal systems. PV systems convert sunlight to electricity directly. Costs are high, but they have been decreasing and this technology may be competitive in rural areas in which distance from the electricity grid makes connection prohibitively expensive.¹⁰ Individual households have made use of PV systems together with a battery, battery-charge regulator and fluorescent lamps. Larger PV systems have proved effective in public places, markets and clinics, as well as in the provision of power for supplying water. Solar thermal systems are effective for heating water, for space heating and for drying

Figure II. Fuel efficiency of various cook stoves

Source: United States Congress, Office of Technology, *Fueling Development: Energy Technologies for Developing Countries* (OTA-E-516) (Washington, D.C., United States Government Printing House, April 1992), p. 296.

Note: An asterisk (*) denotes improved version. Data presented are midpoints of efficiency ranges.

food. They can be used in rural areas where conditions permit.

20. *Wind energy.* Wind energy is used for electricity generation and direct mechanical application. Technical advances have resulted in cost decreases in wind technologies for electricity generation during the past decade and wind power may be suitable for rural areas.¹¹ Wind technologies are site-limited but can compete with conventional systems in some areas. They are more prone to mechanical failure than PV systems. Wind energy is used for pumping water in many rural areas, both for irrigating farmland and for household use.

21. *Modern biomass, including biogas systems.* This refers to the thermal conversion of biomass, such as crop and wood wastes, and the anaerobic conversion of animal wastes, often in household-sized plants, to provide energy for lighting and cooking. Modern biomass is mostly gasification of biomass for use in lighting and cooking or for the generation of electricity.

22. *Geothermal systems.* Geothermal systems are generally associated with large-scale electricity grids for urban areas though they have been applied successfully in rural areas in the Philippines, Indonesia and China. Geothermal energy systems are competitive, in terms of costs, with conventional

fuels for producing electricity and although adverse environmental impacts sometimes occur, they are less damaging than those associated with conventional fuels. Geothermal systems, however, are site-specific and not available in many rural areas.

23. In general, the feasibility of many of the renewable energy technologies is often site-specific, depending on local weather and climate conditions, availability of biomass and animal wastes and, in the case of minihydro projects, topography. Therefore, to promote the development of rural energy supplies, supply-oriented policies must be tailored to meet the specific conditions of each area.

4. Ensuring adequate supplies of energy in rural areas

24. Ensuring adequate energy supplies in general is a responsibility which is being increasingly shouldered by the private sector in developing countries as they undertake structural adjustment programmes calling for privatization of publicly owned industries and the elimination of costly subsidies. Energy production and distribution facilities, such as electricity generating plants and refineries, are being privatized, and subsidies to keep final prices low are being phased out in many countries. Prices of commercially traded

energy may rise as a result and may put pressure on lower cost rural energy supplies such as fuelwood and charcoal as alternative sources of energy, thereby adding to the already existing rural energy shortage in many areas.

25. In the absence of carefully defined contractual relationships between private utilities and the State, relying on the private sector to provide energy services may result in the continued neglect of the energy needs of the rural poor since potential returns on investment in rural areas may be lower than in other areas or non-existent. Appropriate policies must be designed to encourage the private sector or to encourage alternative structures such as local cooperatives to increase the provision of energy in rural areas. Kenya provides an example of successful reliance on the private sector in the solar home lighting market, which totals at least 20,000 solar electric homes, most of which are located in rural areas. Yet barriers have been identified inhibiting the expansion of the rural solar market; they relate to the lack of financing for end-users and the lack of coordinated infrastructure development.¹² For the further penetration of solar technology in rural areas, it is necessary both to train personnel to install and maintain systems, and to ensure the standardization of products and the supply of spare parts.

III. Rural energy policies and rural development

A. Rural development and energy

26. The availability of energy is a necessary condition for economic growth and can facilitate rural development. The availability of affordable energy has been credited with spurring the growth of rural areas in some developed countries following rural electrification programmes earlier this century. The fact that similar efforts in developing countries have not always resulted in economic growth supports the view that the availability of commercial energy is a necessary, but by no means sufficient, condition for rural development.

27. In an effort to achieve more balanced urban/rural growth and alleviate rural poverty, many developing countries are undertaking efforts to promote rural development as part of their overall development policies. This includes the financing of public infrastructure projects, an effort to promote more decentralized decision-making in the public sector and specific tax incentives to encourage businesses and industries to locate in less populated areas. Recognition of the importance of an integrated approach to

rural development, which emphasizes the linkages between energy, agriculture and the environment, is growing.

28. Agricultural reforms often include the elimination of price controls to provide an incentive for farmers to increase output. In many developing countries markets are being liberalized as part of their accession to the World Trade Organization (WTO), and improved trade prospects for agricultural goods are expected to enhance the development prospects of rural areas by stimulating the output of agricultural goods. This implies an increase in inputs such as fertilizer and machinery, both of which may entail greater energy use.

29. Structural adjustment policies and privatization measures, while not specifically related to energy policies in rural areas, may indirectly affect energy demand and supply patterns as well as overall rural development. Previously, tariffs, exchange-rate controls and import quotas designed to protect local industries often had the effect of discouraging exports as well, because they often increased the cost of inputs. Moreover, since agricultural prices were also kept low, exports of agricultural products and other primary commodities were negatively affected. The reversal of these policies is expected to contribute to economic growth in rural areas of many developing countries.

30. Some countries, recognizing the link between rural development and energy availability, are implementing policies aimed at encouraging both in a mutually supportive fashion. China's policies, for example, aimed at both rural and urban areas include ways and means of ensuring energy supplies as economic growth occurs. China is undertaking energy projects to ensure the availability of electricity in many rural areas, including the construction of a number of hydroelectric facilities, and is encouraging the use of non-traditional energy technologies in rural and remote areas. These include biogas plants and programmes for the widespread distribution of efficient cookstoves. China has also initiated efforts at decentralizing the decision-making process to facilitate the evaluation of energy projects at the local level so that energy and developmental needs can be considered together.

31. India has initiated energy policies in line with rural development programmes, including those aimed at encouraging the use of non-traditional supplies of energy. Its Integrated Rural Energy Programme is designed to promote energy-related decisions at a decentralized level so that measures are more in line with rural development plans. It has actively encouraged the use of biogas plants, PV systems, wind technology and improved cookstoves in rural areas. Furthermore, India has the potential to develop

significant and largely untapped hydro resources for rural and urban uses

B. Financing rural energy projects

32. In the past, a number of constraints existed on the financing of rural energy projects, including the preference for centralized electricity systems, relatively low prices of conventional fuels and electricity resulting from subsidies and the paucity of loanable funds resulting from macroeconomic policies aimed at maintaining low interest rates. These factors contributed to the low investment in the energy systems of rural areas in many developing countries. In addition, rural areas may be viewed as high risk by individual investors and financial markets. Moreover, energy projects feasible in remote areas with low population densities may be too small to attract investment capital and/or funding from financial institutions. Financing may also be required for energy-saving appliances such as efficient cookstoves, which may be cost effective over a lengthy time period but which have relatively high initial purchase prices, too costly for low-income rural dwellers. Utility companies have an incentive to provide such financing and are doing so in a number of countries.

33. Some of these constraints are being eliminated gradually in countries undertaking economic reform, including the reduction and elimination of subsidies for conventional energy services and products, and the privatization of publicly owned companies, which often include electricity facilities, refineries and energy service distribution networks. However, institutional support in terms of credit arrangements and financing may still be required in rural areas, especially if Governments undertake efforts to encourage the application of renewable energy technologies. In certain instances, government-backed lending policies as well as support of microcredit schemes and other innovative lending arrangements may be justified.

34. Community-based financing of small units designed to serve small dispersed communities in remote areas may be most appropriate especially when income levels are very low. Renewable energy technologies such as minihydro facilities, PV systems and wind power, which may be competitive but which have relatively high start-up costs, could become the system of choice with the availability of financing. Cooperative arrangements in which the community is involved in the decision-making process have been successful in some countries in providing electricity services.

35. India has been providing support to wind and other renewable energy projects for the past decade. Financing with attractive interest rates to developers of up to 75 per cent of renewable energy projects, tax breaks and financial incentives for provincial electricity boards have helped increase total installed capacity of renewable energy from 200 MW in early 1995 to almost 850 MW. India expects the private market to continue financing such projects as it gradually withdraws government support.

36. The Grameen Bank of Bangladesh has initiated a programme to provide credit for renewable systems to serve those without access to electricity, through a non-profit rural energy company established in 1996. Loans are made for solar home systems using photovoltaic systems with small down payments. It expects that 100,000 PV systems will be operating in rural area homes by the year 2000. The bank plans to expand this service by offering small loans for wind power and biogas plants, and demonstration projects are currently under way to determine the most appropriate financing package.

37. Community-based financing of small-scale grids in rural areas has been facilitated by the participation of non-governmental organizations in some countries. In Peru and Nepal, for example, non-governmental organizations have provided credit for small grids powered by minihydro systems. Moreover, demonstration projects have made use of microfinancing for renewable energy technologies such as PV stand-alone systems and biogas plants, in some cases.

38. In addition, a number of international organizations are currently looking further into ways to finance renewable energy technologies mainly aimed at providing electricity services to rural areas. International organizations as well as bilateral aid arrangements have also provided funding for comprehensive energy programmes as well as individual demonstration projects for applications of renewable energy technologies in most regions of the world. Some of the government-supported programmes, for example those in China, India and Argentina, receive partial funding from the World Bank and other funders. However, these types of activities could be expanded at the national, regional and international levels. An innovative financing programme was recently established as a private fund with government guarantees in Eastern Europe to provide financing for PV systems and delivery channels, which could spur PV sales in rural areas from 10-20 MW annually to 100-200 MW annually in five years, without the need for costly subsidies.

39. The Conference of African Ministers responsible for the Development and Utilization of Mineral Resources and Energy recently recommended that revenues from electricity

tariffs and taxes on petroleum products be used for financing rural electrification in Africa.

C. Rural energy development and the local environment

40. Issues related to the environmental impact of the development and use of energy in rural areas have not received the attention they deserve and information about the impact of such policies, when they have been undertaken, is scarce. An exception is Kenya, which has undertaken a number of initiatives designed to promote better management of all resources at the community level in rural areas. To combat deforestation, the Kenya Energy and Environment Non-Government Organization has programmes to disseminate information about efficient wood-burning stoves and for the promotion of reforestation. The Participatory Rural Appraisal programme encourages community development for resource management at the village level.

IV. Rural energy policies as part of national energy policies

A. Pricing policies

41. Many countries have implemented measures to maintain below market prices for energy products and services, including those commonly used in rural areas. Electricity is often subsidized, as are kerosene, LPG and diesel fuel. Although intended as a benefit for low-income groups as a way of providing for basic needs, and as a means of encouraging economic development, these measures, in the long term, have in many cases led to greater-than-optimal levels of consumption and have contributed to fiscally untenable positions of electricity facilities and refineries, often government-owned and operated, as revenues have not been enough to cover costs. The quality of service has suffered as a result of subsidized pricing policies. In some countries, such policies have resulted in the overuse of related products, such as pumped water. Partly to rectify these problems and partly to encourage private-sector involvement in the energy service industries, many countries have begun to reduce subsidies, usually at a graduated pace.

42. Subsidies have also been criticized for benefiting higher income classes more than the poorest segment of society. This is especially relevant in rural areas since, as

noted earlier, the poor often do not purchase energy services in the market, but gather their own fuel.

43. Price subsidies on electricity and the extension of the national grid in many countries has also been attributed to influencing the choice of energy services where non-traditional energy supplies may be more efficient. Price subsidies have been necessary in connecting many rural areas to a national electricity grid since connection costs are often too high to be passed on to rural consumers. In some cases lifeline pricing and cross-subsidization may be justified. With lifeline pricing, a low price is charged to those utilizing minimal levels of electricity. As incomes increase, electricity use grows and higher prices are charged for incremental amounts used. Higher unit prices on the greater amounts used cover the costs of subsidization. This is effective in areas where development is occurring and incomes are growing. With cross-subsidization, higher-income users are charged a higher rate to cover costs of lower-income users, who are charged below-cost prices. These pricing schemes have the advantage of providing electricity to the poor without negatively affecting the financial solvency of the electricity company. However, the gradual reduction of subsidies is expected to positively affect the prospects of alternatives to the national grid in remote areas with low population densities. PV lighting systems, minihydro systems and other renewable energy technologies may be better able to compete with electricity supplied from the national grid in the absence of price subsidies.

B. Incentives for developing national energy resources

44. Rural areas often face unique obstacles which discourage private sector initiatives in developing energy sources. In remote areas that are difficult to reach, it may be costly to transport fuels and provide energy services. Low population densities may render average cost pricing for such services prohibitively expensive for typically poor rural dwellers. Some incentives may be required to encourage the development of national energy sources in rural areas. These incentives have constituted a significant part of rural energy policies in many developing countries and have ranged from rural electrification programmes to the distribution of more efficient cookstoves and the promotion of biogas plants in rural areas.

45. Rural electrification programmes have typically concentrated on connecting rural villages and remote areas to a national grid often owned and operated by the

Government. Thailand is considered a success story as its rural electrification programme, which began in 1974, has increased the proportion of electrified villages from 20 per cent to 98 per cent. The success of the programme is credited to careful expansion planning, efficient billing, a cross-subsidizing rate structure designed to charge large users higher amounts than small users, responsiveness to customers and marketing programmes.

46. Kenya's Rural Electrification Programme provides incentives to consumers to connect to the electricity grid where available. Under this programme, the consumer is required to pay only a token connection fee (\$40) and a small meter charge (\$5) compared with actual connection costs, estimated to be at least \$1,640. Connections have been averaging 5,000 per year during the 1990s, but the programme is hampered by lack of funds. Only 3.4 per cent of the electricity supplied by the national grid reaches rural customers.

47. Argentina has recently begun implementing an innovative rural energy plan designed to encourage private-sector involvement in providing rural energy services to four provinces initially. In each province private companies bid for the right to provide electricity services to the previously unserved population, expected to total 1.4 million people and 6,000 public buildings. Electricity may be provided by any energy source but officials expect that most will utilize renewable energy sources and that 80 per cent of the electricity will be provided through PV home systems. Fifty per cent of costs will be covered by tariffs, 30 per cent by provincial funds and 20 per cent will be provided by the federal Government with assistance from the World Bank. Total investment in the four provinces is expected to be \$300 million and cross-subsidies between the grid and rural customers will not be allowed. This programme holds promise for rural electrification throughout the country and eventually all rural provinces will participate.

48. China's energy programme includes specific energy policies aimed at rural areas ranging from the development of local resources such as mini-hydro systems to the distribution of efficient cookstoves. As a result of its ambitious cookstove programme, over half of China's farmers have efficient cookstoves, and fuelwood savings are estimated at between 25 per cent and 33 per cent. China has also actively encouraged the use of biogas plants and there are now 5 million family-sized biogas plants in use in rural areas throughout the country. Mini-hydropower is also utilized in areas where water resources are suitable and there are now more than 60,000 units with total installed capacity of more than 17 GW. Though conventional energy development and distribution are still largely controlled by

the central Government, China has made efforts to decentralize rural energy decision-making and, as noted above, is also incorporating specific energy measures in overall developing planning, with a view to promoting sustainable development.

49. Policies aimed at improving rural energy systems in India have been undertaken under the auspices of the Ministry of Nonconventional Energy Sources and have included the National Project on Biogas Development and the National Programme on Improved Chulhas (cookstoves). These programmes are expected to benefit between 10 per cent and 15 per cent of total rural households in India by the end of the century and focus on increasing energy efficiency through better technology. In addition, India has a programme to encourage PV systems using national manufacturing capabilities financed by national funds as well as the Global Environment Facility.

50. Policies designed to encourage sustainable forestry consumption and production patterns and the efficient management of forest resources may also have a positive impact on energy supplies in rural areas. Some countries, including Burkina Faso, Niger, India and the Republic of Korea, have placed forest resources under the management of local authorities to ensure policies best suited to local needs.

C. Environmental policies

51. A major obstacle in the adoption and implementation of environmental policies specifically aimed at avoiding or reducing environmental impacts associated with energy use, is the problem of harmonizing environmental and energy policies at the national level.

52. Environmental regulations in many developing countries are undertaken mainly to solve localized pollution problems typically resulting from urbanization and industrialization. Measures directed towards rural areas in some countries are aimed at preserving forest areas by prohibiting firewood collection but these are often ignored by local rural dwellers. Enforcement is difficult without the cooperation of local residents. Policies undertaken in some countries to combine firewood collection regulations with agro-forestry and afforestation programmes may be more effective since they may offer local residents a viable alternative to firewood collection.

V. Conclusions and recommendations

A. Rural energy policies and rural development

53. Policies for rural development and those aimed at enhancing rural energy services should be developed and implemented in a mutually reinforcing way:

(a) Developing countries should include rural energy as part of overall rural development strategies. To this end, appropriate government agencies within the ministry responsible for national energy policy should be assigned specific responsibility for rural energy. In some cases the most appropriate agency may be at the provincial or local level;

(b) Further efforts at the local, national and international levels should be undertaken to provide quantitative and qualitative information on the availability and use of energy from all sources in rural areas for use by policy makers;

(c) Rural development policies should be initiated and/or strengthened. In this context the bias towards urban development in the policies of many developing countries should be eliminated and, *inter alia*, macroeconomic policies adopted at the national level should not favour urban areas at the expense of rural areas;

(d) The provision of electricity to unserved rural populations should be a priority, undertaken on the basis of programmes for specific regions over periods of 5 to 10 years;

(e) For rural areas not connected to grids, sustained programmes of investment in decentralized rural energy schemes, based on renewable energy, where reasonable, should be launched, with the incremental cost of such schemes to be met, where necessary, from global sources such as the Global Environment Facility;

(f) Changes in the energy-service mix demanded by rural dwellers should be monitored for environmental impacts in order to adjust environmental policies in a timely fashion.

B. Energy pricing in rural areas

54. In rural areas, as elsewhere, rational pricing of energy is necessary to encourage conservation and efficient use. The principle instruments for correcting energy prices in rural areas are the removal of subsidies and/or poorly designed

price controls. Governments should seek to implement such changes while reducing their possibly negative effects in three ways:

(a) Implementation of differential pricing for electricity, by establishing low or "lifeline" tariffs to poor households and very much higher tariffs to wealthier consumers, such that the average price for the sector reflects the full marginal costs of supply;

(b) The elimination of politically motivated price controls, shifting the responsibility for determining and monitoring price guidelines to independent regulatory authorities, with consumer representation and acting within the framework of transparent rules;

(c) Increasing prices gradually so that consumers develop an in-built expectation that energy prices will rise through time, enabling consumers to plan to adjust their consumption.

C. Meeting the costs of financing energy supply

55. An increasing number of countries are relying on the private sector for the provision of energy services, which becomes possible in the context of pricing reform. While this trend has positive ramifications, particularly for the efficient use of resources, there may not be enough incentives for the private sector to provide energy services to low-income, low-density rural areas:

(a) At the national level, there is need for innovative financing arrangements in rural areas, especially for low-income rural dwellers. Microfinancing arrangements with initial grants from the Government may be appropriate in some areas. Cooperative arrangements for the supply of certain energy services may be facilitated with credit arrangements as well. Incentives in the form of licensing agreements may encourage the private sector to provide certain energy services in rural areas;

(b) At the regional and international levels, aid programmes for the development of rural energy services should also be designed to support private-sector involvement in rural areas. Technical assistance in establishing and operating microcredit schemes specifically for the provision of energy services in rural areas may be among important activities appropriate for such programmes in many countries.

D. Improving the enabling environment for renewable energy

56. Renewable energy technologies hold promise for providing energy services to some remote rural areas owing to recent technical advances which have resulted in lower costs, rendering such technologies competitive in some rural areas:

(a) At the national level, there is a need to raise awareness and educate consumers about the advantages and disadvantages of renewable energy technologies most suitable for rural areas. Existing extension programmes may be utilized for such activities in some areas while, in other areas, extension programmes should be established and/or strengthened to undertake this type of activity;

(b) Programmes and projects to disseminate information and provide training about successful programmes in other regions may be suitable for funding by regional and international organizations;

(c) Programmes should be established to provide institutional support for renewable energy systems by encouraging and facilitating distribution systems;

(d) At the national level, there is a need for technical training programmes to enable the periodic maintenance required for the efficient operation of many renewable systems as their use spreads.

Notes

¹ *Official Records of the Economic and Social Council, 1996, Supplement No. 4 (E/1996/24)*, chap. I, sect. B, draft decision II.

² D. F. Barnes, R. van der Plas and W. Floor, "Tackling the rural energy problem in developing countries", *Finance and Development*, vol. 34, No. 2 (June 1997), p. 12.

³ *World Urbanization Prospects: The 1996 Revision* (forthcoming United Nations publication).

⁴ United Nations Development Programme, *Energy After Rio: Prospects and Challenges* (New York, 1997), p. 28; and Food and Agriculture Organization of the United Nations, *Agriculture: Towards 2010* (Rome, 1995).

⁵ World Bank, *Rural Energy and Development* (Washington, D.C., 1996) p. 21.

⁶ Food and Agriculture Organization of the United Nations, *Energy for Sustainable Development and Food Security in Africa* (Rome, 1996).

⁷ J. W. Sun, "Real rural residential energy consumption in China, 1990", *Energy Policy*, vol. 24, No. 9 (1996), p. 829, based on official 1990 statistics.

⁸ World Bank, *Rural Energy and Development ...*, p. 42.

⁹ D. F. Barnes, R. van der Plas and W. Floor, loc. cit., p. 12.

¹⁰ See *Proceedings of a Seminar on Sustainable Development of Rural Areas: Decentralized Electrification*, Marrakesh, 13-17 November 1995.

¹¹ See the report of the Secretary-General on renewable sources of energy, with special emphasis on wind energy (E/C.13/1998/4).

¹² M. Hankins, "Limits of the market approach for the PV rural electrification in Kenya", in *Proceedings of a Seminar on Sustainable Development of Rural Areas: Decentralized Electrification*, Marrakesh, 13-17 November 1995, pp. 97-103.

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Energy and sustainable development

Energy and transportation**Report of the Secretary-General***Summary*

The transportation sector has been the major source of growth for oil demand over the past 25 years, and is expected to continue to be so in the medium term. During the period 1970-1994, world transportation energy demand grew at an average annual rate of about 1.9 per cent. In the Organisation for Economic Cooperation and Development (OECD) countries during this period, major transportation fuels demand increased at an annualized rate of about 1.4 per cent; in developing countries, as is to be expected considering their currently low levels of consumption, growth rates in major transportation fuels consumption were higher, exhibiting an average annual growth rate of about 5.3 per cent. There was a marginal decline in the transportation fuel demand of non-OECD Europe during this period.

The transportation system relies nearly completely on petroleum-based fuels, accounting for almost 60 per cent of final world oil consumption; the growing concerns over its environmental impacts, particularly greenhouse gas emissions, have stimulated research and development of alternative fuels and technologies. However, alternative fuel vehicles remain a small fraction of the total world vehicle stock.

Environmental impacts of transportation continue to be very large, but a few countries have made much progress in reducing some impacts, in particular vehicular emissions by means of catalytic converters and cleaner fuels. Carbon dioxide emissions, the major greenhouse gas of concern, continue to increase, which is unavoidable as it is a by-product of fossil fuel combustion. However, the environmental impacts of transportation are not confined to the combustion of transportation fuels but occur throughout the entire vehicle and fuel cycle.



Governments have a significant role to play in reducing the environmental impacts of the transportation sector by putting in place and implementing an energy policy for the transportation sector that promotes improvements in transportation efficiency and the use of alternative fuels.

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I. Introduction

1. The report reviews global transportation trends, with particular emphasis on the major transportation consumer countries and the transport demand growth in developing countries. Both developed and developing countries are facing similar challenges, resulting from increasing mobility and freight activity as well as from a shift in modes – for both passenger and freight transportation, motor vehicles are gaining increasing modal shares, often at the expense of other modes.

2. Historically, the correlation between economic growth and the demand for transport has been strong, although this relationship may be moderated in the major economies by the increasing “dematerialization” of their economies. However, the demand for freight service in those economies is shifting towards faster and more flexible but more energy-intensive transportation system.

3. Environmental concerns over the increasing impacts of transportation fuels emissions and the near total dependence of transportation on petroleum products continue to stimulate interest in alternative fuels. The present report provides a brief review of a variety of alternative or replacement fuels and vehicles that are being tested, demonstrated and marketed.

4. The scope of the report is largely confined to the use and related environmental problems of transport fuels. Policy responses to those problems are not extensively treated in the report, although it is clear that transport policy can influence emissions of greenhouse gases and other gaseous as well as solid pollutants from transportation activity. Public policy responses to transportation infrastructure and land use, modal shifts and air quality, especially in urban areas, have had measurable success in many countries (for a useful discussion of policy approaches in energy and transport, see E/CN.17/1997/17/Add. 1).

in terms of accidents, pollution and the degradation of ecosystems and landscapes.

6. Although the exact relationship between transport and economic activity varies with the level of economic development, historical data confirm the relationship of GDP per capita to transport demand, as shown in figure 1. Countries with high transport energy use relative to countries with similar income levels tend to have low population densities and/or lower relative prices of transportation fuels. Rising levels of transport activity have accompanied rapid economic development in a number of developing countries. Further changes in transportation demand and services can be expected in many developing countries, given that their development strategies are now focused on shifting from the processing of raw materials to the production of semi-processed and finished goods, higher unit value and lighter density.

7. In countries of the Organisation for Economic Cooperation and Development (OECD) growth in transport activity has closely tracked growth in GDP. Table 1 indicates average annual growth in GDP and transport activity in OECD countries. The importance of transport demand to the economy can be measured as the share of transport-related final demand in GDP. In the case of the United States economy, in 1995 total transportation-related demand was about 10.7 per cent of GDP, at about US\$777.2 billion.¹

Table 1

Annual growth in gross domestic product and transport, OECD countries, 1975-1990

	GDP	Freight traffic	Passenger traffic
OECD – Europe	+2.6	+2.8	+2.8
United States	+2.8	+2.6	+2.3
Japan	+4.2	+3.6	+2.6

Source: World Energy Council, *Global Transport Sector Energy Demand Towards 2020* (1995), p. 27.

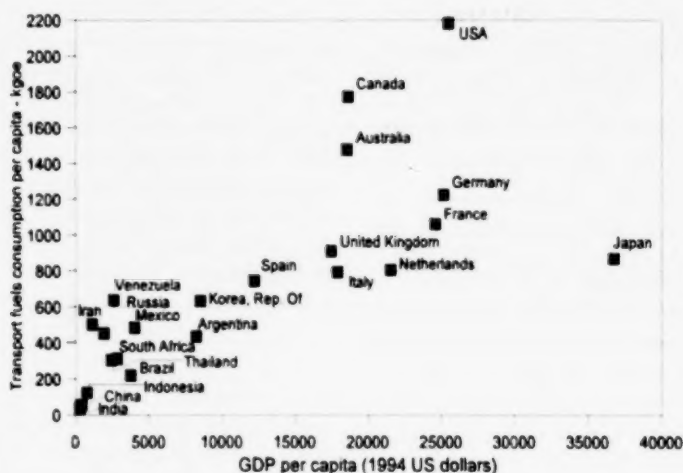
II. Transportation and the economy

5. Transportation is an important component of any economy and makes a substantial direct contribution to gross domestic product (GDP). It provides valuable employment opportunities, and has large indirect benefits in facilitating national and regional development and globalization. Transportation, including equipment, travel and freight shipments, is one of the fastest growing sectors of the world economy. However, transportation also imposes considerable costs on society and the environment, notably

8. The public sector incurs large expenditures to build, maintain and regulate roads, mass transit facilities, ports and waterways, railroads and pipelines. In many countries, most of the direct costs of building and maintaining transportation infrastructure are recovered from user taxes and fees and through general tax revenues. The important role of the transport sector in improving general economic performance is widely accepted by policy makers, as manifest in their emphasis on investments in transport infrastructure since an efficient transport system is essential in the modern global economy.

Figure 1

Transport energy use vs. gross domestic product, selected major users of transport fuels, 1994



Source: Department of Economic and Social Affairs of the United Nations Secretariat, based on United Nations, *Statistical Yearbook*, forty-first edition, and *Energy Statistics Yearbook*, 1994.

III. Energy and transportation

9. Over the next 20 years, growth in demand for transportation services is expected to be the major cause of growing world oil demand, as it has been over the past 25 years, despite large increases in oil prices on two occasions. During the period 1970-1994, transportation energy demand grew at an average annual rate of about 1.4 per cent in OECD countries, while in developing countries it increased at about 5.3 per cent. The transport sector has not altered its near total dependence on petroleum products. Passenger cars are the main users of transportation energy, and the increase in vehicle-kilometres travelled has more than offset the increase in average vehicle fuel economy. Rapid growth in heavy truck and airline travel has also increased the demand for transportation energy. Increased use of heavy trucks substantially outpaced modest efficiency gains, and in the airline industry a rapid surge in passenger-miles travelled offset a substantial increase in per-passenger fuel economy.²

10. In 1970, total world consumption of motor gasoline, diesel oil and aviation fuels – the major transportation fuels – was about 1,135.7 million tons of oil equivalent (Mtoe), representing about 50 per cent of the total oil consumption

of about 2,271.1 Mtoe, or about 26 per cent of total world commercial energy demand. By 1985, the major share of world total oil demand was for transportation fuels, their “cut of the barrel” having increased to about 55 per cent. In 1994, world demand for the major transportation fuels increased to more than 1,810 Mtoe (over 36 million barrels of oil per day), at an average annual increase of about 1.9 per cent during the 25-year period since 1970. The transportation fuels share of the total crude oil used (about 3,041.1 Mtoe) increased substantially to about 60 per cent, while their share of the total world commercial energy demand (7,880.6 Mtoe) declined to about 23 per cent (marine bunker fuels are not taken into consideration in the present report because of the difficulty in acquiring reliable data that would permit the correct attribution of fuel consumption to the countries concerned).

11. It is noteworthy that the transport sector is the only major sector of the economy in which consumption of crude oil has been increasing in the developed countries; in contrast, in developing countries oil demand has increased in all sectors of the economy. In OECD countries over the past 25 years, the transportation sector has remained almost totally dependent on oil products, while other sectors of their

economies have shifted away from oil. Oil use has declined in the residential and commercial buildings sector, as well as in the utility sector, although industrial oil use has remained stable, primarily due to the importance of petroleum as feedstock in the petrochemical industry.³

12. The share of world total major transportation fuels consumption of the OECD countries has been declining since 1970, from about 75.3 per cent to 65 per cent in 1990, but it marginally increased to 66 per cent in 1994. The decline in the share of OECD countries was largely the result of gains in the Asia and Pacific region, where its share of 4.8 per cent in 1970 increased significantly to about 12.8 per cent in 1994. Similarly, during the period 1970 to 1994, transportation fuels consumption in the Middle East region increased their share from about 1.1 per cent to 5.1 per cent, while the Latin America and the Caribbean region registered a relatively moderate gain, from 4.2 per cent to 5.5 per cent (see figure II).

13. During the 25-year period 1970-1994, the consumption of transportation fuels in OECD countries increased from about 855.8 Mtoe in 1970 to over 1,197.5 Mtoe in 1994, representing an average annual gain of about 1.4 per cent. Of the fuels, aviation fuels registered the highest growth rate of over 2.3 per cent, while motor gasoline gained 1.5 per cent and diesel oil gained the least – about 1 per cent. As is to be expected, growth rates in transportation fuels consumption were higher in the developing world given the starting point of very low levels of consumption. During the period under consideration, the average annual growth rate in consumption of transportation fuels was highest in the Middle East region, having increased substantially by 8.4 per cent from 12.5 Mtoe to about 90.3 Mtoe, followed by that in the Asia and the Pacific region for about 6.1 per cent from 52.4 Mtoe to 231.3 Mtoe. An average annual gain of about 4 per cent was registered in Africa, and in Latin America it was about 3 per cent. Very large differences in total consumption of transportation fuels in the different regions and groups of countries are clearly illustrated in figure III; the differences would be even greater if shown on a per capita basis.

14. Motor gasoline and diesel oil account for the bulk of the transportation fuel used worldwide and taken in conjunction with the dominance of road transport among the different transport modes, motor vehicle registration would be a fairly good indicator of transportation energy consumption trends. Total passenger car registration in the world, as shown in table 2, increased significantly from about 194.1 million cars in 1970 to about 458.5 million by 1994. In the same period, commercial vehicles increased from 49 million to about 133.6 million. Passenger car

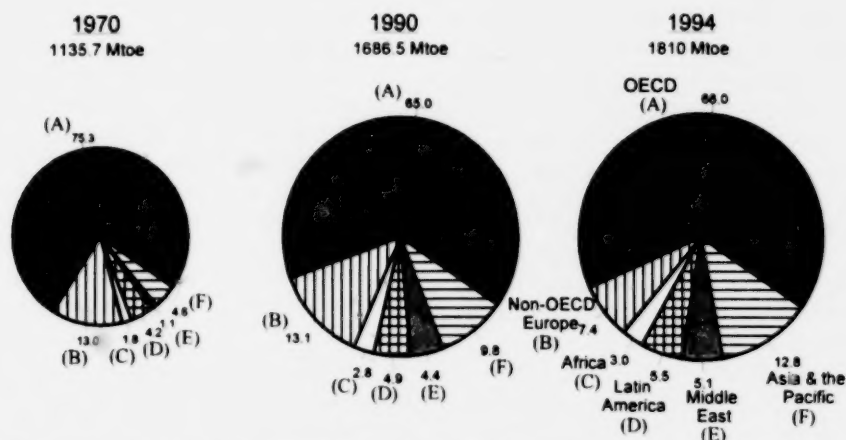
ownerships in the OECD countries increased from 176.3 million cars in 1970 to about 384.9 million by 1994, while in the same period in non-OECD Europe and the rest of the world, passenger cars registration increased from about 17.8 million cars to about 73.6 million. In 1994, OECD countries – with a share of less than 20 per cent of the world's population – accounted for over 80 per cent of the total motor vehicle registration in the world – almost 83 per cent of the total passenger cars. Evidently, in the past 25 years there has been a tremendous increase worldwide in transportation activity as measured by passenger-kilometres, ton-kilometres and vehicle kilometres travelled. Almost all of the increase in transportation services was captured by road passenger and freight transport.

15. The growth rate in total world motor vehicle registration appears to have been on a linear trend during the 1970s and the 1980s, but the growth rate has slowed somewhat in the period 1990-1994, and may continue to be lower than in the past; the recent financial crisis affecting many of the newly industrializing economies may also contribute to reducing demand.

16. Table 3 shows aggregate passenger and commercial motor vehicles in use in selected countries, differentiated by income levels and on a per capita basis for passenger cars. It clearly illustrates the enormous differences in terms of population per passenger car, from a level of over 636 per car in China to less than 2 persons per car in the United States of America and under 3 per car in the other high-income economies of OECD. The number of motor vehicles in developing countries remain a small fraction of that of in the high-income countries, but there is greater potential for growth in developing countries, since not surprisingly, ownership rates are expected to grow more rapidly in the economies with the fewest vehicles. Despite higher growth rates of car ownership in developing countries, OECD countries will clearly continue to dominate in total car registrations. The 2 per cent average annual growth in passenger cars in the United States between 1970 and 1994 represented an increase of 58.3 million new cars on the road, more than 10 times as many as the 5.1 million additional passenger cars in the Republic of Korea as a result of a remarkable annual growth rate of 19.4 per cent during the same period.

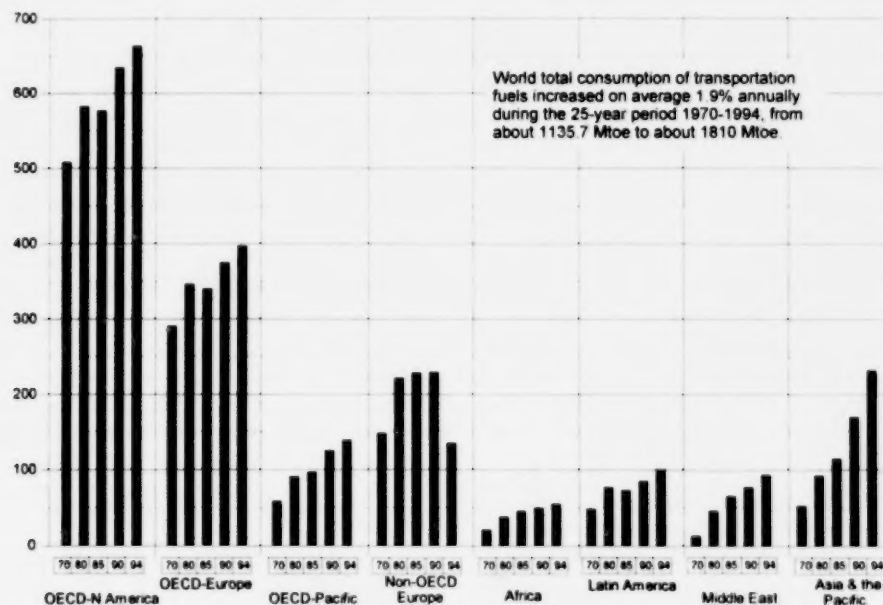
17. With the substantial increase in ownership, passenger car occupancy levels have declined considerably in OECD countries, and have increased the tendency towards low load factors for commercial vehicles. In contrast, despite relatively rapid growth in motor vehicle use in developing countries, buses and trucks, and for that matter trains, are

Figure II
Share of total major transportation fuels consumption, by region
 (Percentage)



Source: Department of Economic and Social Affairs of the United Nations Secretariat, based on *Energy Statistics Yearbook* (United Nations publication), various issues.

Figure III
Total consumption of major transportation fuels, by region, 1970-1994
 (Million tons of oil equivalent)



Note: The major transportation fuels are motor gasoline, aviation fuels and diesel oil; non-OECD Europe consists of Eastern Europe and the Republics of the former USSR.

Source: Department of Economic and Social Affairs of the United Nations Secretariat, based on *Energy Statistics Yearbook* (United Nations publication), various issues.

Table 2
Motor vehicles in use worldwide, 1970-1994
(Thousands of units)

Region	Shares of total (percentage)								Annual growth	
	Passenger cars		Commercial		Passenger cars		Comm. vehicles		A ^a	B ^b
	1970	1994	1970	1994	1970	1994	1970	1994		
World	194 140	458 489	49 040	146 501	100	100	100	100	3.5	4.5
OECD	176 325	384 871	40 644	102 030	90.8	82.9	83.9	69.6	3.2	3.8
Non-OECD										
Europe	4 686	15 487	2 455	12 885	2.4	5.0	3.4	8.8	4.9	6.9
Africa	3 290	9 411	1 297	4 887	1.7	2.6	2.1	3.3	4.3	5.4
Latin America	6 403	20 497	2 362	6 359	3.3	4.8	4.5	4.3	4.8	4.0
Middle East	963	9 065	364	4 523	0.5	0.7	2.0	3.1	9.4	10.6
Asia & the Pacific	2 474	19 158	1 918	15 818	1.3	3.9	4.2	10.8	8.5	8.8

Note: In a number of countries, motor vehicles in use in 1994 were estimated.

Source: Department of Economic and Social Affairs of the United Nations Secretariat, based on the *Statistical Yearbook* (United Nations publication), various issues.

^a Passenger cars.

^b Commercial vehicles.

Table 3
Motor vehicles in use and population, selected countries^a
(Thousands of units)

	Total Passenger cars		Total Commercial vehicles		Annual growth rate (percentage)		Population per car
					Cars	Commercial	
	1970	1994	1970	1994	1970-94	1970-94	1994
Low-income economies							
China	133.0	1 900.0	480.0	1 513.0	11.2	4.7	636.2
Egypt	130.7	1 225.0	35.4	445.0	9.4	10.7	47.2
India	627.2	3 330.0	413.9	2 396.7	6.9	7.3	275.8
Kenya	95.9	171.5	18.0	172.8	2.4	9.5	170.8
Nigeria	57.0	227.0	40.0	22.3	5.7	-2.3	477.8
Pakistan	154.5	955.1	63.6	359.5	7.6	7.2	132.6
Lower-middle-income economies							
Algeria	142.8	725.0	81.6	480.0	6.7	7.3	37.7

	Total Passenger cars		Total Commercial vehicles		Annual growth rate (percentage)		Population per car
	1970	1994	1970	1994	Cars	Commercial	
					1970-94	1970-94	1994
Colombia	238.5	761.7	83.5	672.6	4.8	8.7	45.3
Indonesia	238.9	1 890.3	125.9	1 903.6	8.6	11.5	101.7
Iran (Islamic Rep. of)	278.2	1 557.0	73.5	588.9	7.1	8.7	38.4
Poland	479.4	7 153.1	259.9	1 395.1	11.4	7.0	5.4
Czech Rep.	825.8	2 917.3	198.6	336.2	5.2	2.1	3.5
Thailand	184.7	1 798.8	162.8	2 384.1	9.5	11.3	33.0
Tunisia	66.4	325.0	37.2	222.0	6.6	7.4	26.9
Turkey	137.8	2 861.6	159.8	530.4	12.9	4.9	21.4
Upper-middle-income economies							
Argentina	1 439.6	4 427.0	754.8	1 239.0	4.6	2.0	7.7
Brazil	2 324.3	8 098.4	696.2	1 839.0	5.1	4.0	19.0
Hungary	240.3	2 176.9	159.4	297.1	9.2	2.5	4.7
Malaysia	279.4	2 333.0	31.0	422.0	8.9	11.0	8.5
Mexico	1 233.8	8 451.1	588.9	3 839.4	8.0	7.8	11.0
Republic of Korea	60.7	5 148.7	64.7	2 226.7	19.4	15.2	8.7
Saudi Arabia	64.9	2 664.1	50.4	2 272.8	16.0	16.5	6.6
South Africa	1 544.5	3 488.6	428.2	1 784.9	3.3	5.9	11.6
Venezuela	565.8	1 579.0	198.2	460.0	4.2	3.4	13.4
High-income economies							
Australia	3 898.5	8 209.0	971.5	2 151.0	3.0	3.2	2.2
Canada	6 602.2	13 639.4	1 481.2	3 764.9	2.9	3.8	2.1
France	12 900.0	24 900.0	2 904.0	4 027.0	2.7	1.3	2.3
Germany	14 673.4	32 652.0	1 398.6	2 826.0	3.3	2.9	2.5
Israel	151.2	1 057.5	89.2	251.7	8.1	4.2	5.1
Italy	10 181.2	29 600.0	1 306.7	2 745.5	4.4	3.0	1.9
Japan	8 832.1	42 679.0	8 740.5	20 916.0	6.5	3.6	2.9
Netherlands	2 258.0	5 883.9	293.0	687.3	3.9	3.5	2.6
Singapore	147.1	340.6	37.5	136.8	3.4	5.3	8.6
Spain	2 377.7	13 733.8	741.0	2 952.8	7.3	5.7	2.9
United Kingdom	11 665.8	21 740.0	1 709.9	2 994.0	2.5	2.3	2.7
United States	88 840.5	147 171.0	17 978.4	48 298.0	2.0	4.0	1.8

Source: Department of Economic and Social Affairs of the United Nations Secretariat, based on *Statistical Yearbook* (United Nations publication), various issues.

* Country classification based on World Bank *World Development Report*, 1994 (Oxford University Press).

almost always overloaded with people and goods, often leading to safety problems, a situation that is unlikely to change in the near future. People in developing countries rely heavily on public and non-motorized transportation, such as bicycles and cycle-rickshaws (particularly in Asian cities), including foot travel.

18. As noted, the transport sector is almost totally dependent on petroleum products, and it is evident that its demand for oil will continue to increase substantially. Although there have been significant improvements in energy efficiency over the past 20 years, the efficiency gains appear to have tapered off or stalled for the largest energy-using modes. The efficiency gains in transport energy use prompted by the oil price increases in the 1970s had until recently been restraining the growth in transport energy demand. But after the sharp decline in oil prices in 1986, improvement in transportation energy efficiency appears to have slowed down almost to a halt. This may have significant ramifications on the world energy market since nearly all transport energy demand projections, particularly for OECD countries, have been based on the premise of continued improvements in transportation energy efficiency.

19. Furthermore, oil supply will not be a constraint to continued growth in world transportation energy demand. Currently, the world oil reserves to production ratio appears to be sufficient to meet total world oil demand for the next three decades and more, even if there should be a strong surge in transportation energy demand. Current trends indicate continued growth in world transportation energy demand in developing countries, underpinned by the strong correlation between economic growth and the demand for transport as demonstrated by historical data, and in high-income economies this relationship may be moderated by the increasing "dematerialization" in production, i.e., producing fewer tons per dollar of GDP. However, in OECD countries the demand for freight services is shifting towards faster and more flexible but energy-intensive transportation system. This shift to road-freight transport and much increased use of air freight, is largely due to the two interlinked trends in production, the move towards production of lighter high-value goods and the expanding use of "just in time" production techniques, requiring smaller and more frequent deliveries, which are best provided by road and air transport.⁴

20. International aviation travel and freight transport has grown tremendously during the past 25 years, as a result of economic growth, falling airline tariffs and technical advances. Air transport has played an important role in shaping the global economy. Decreasing air fares in a time of increasing real wages and the inherent time-saving aspect

of air travel are the main contributors to the high growth rate in passenger traffic. Since 1960, air passenger traffic has expanded at an average annual rate of about 9 per cent and air cargo by 11 per cent.⁵ World demand for aviation gasoline and jet fuels increased from about 108 Mtoe in 1970 to more than 180 Mtoe in 1994. World air travel is dominated by OECD countries, where aviation fuels consumption increased from about 72.4 Mtoe to 128.1 Mtoe during the same period, while in developing countries it increased from 12.3 Mtoe to 37.1 Mtoe. Growth in air travel has been more rapid than growth in travel by passenger car, with revenue air passenger miles having increased at an average annual growth rate of 6.8 per cent in the period 1970-1992.⁶

21. The relative position of the railway sector in the transportation system has remained fairly unchanged during the past two decades. Although it plays a vital role in freight transport in the OECD countries, overall rail freight volume in those countries has declined, but with significant differences among individual countries. In developing countries, both passenger and freight transport volumes have increased, especially in the larger developing economies. Rail passenger transport plays an important role in personal mobility in a number of developing countries. In China and India, each of their railways carry more passenger traffic than the combined railways of all OECD-Europe and the United States. In India, per capita passenger-kilometres travelled by rail are more than twice as high as in the United States. The type of rail traction used varies, with electric traction more heavily relied upon in Europe and Japan, and diesel traction more common in North America, Australia and the developing countries. Primary energy use does not differ significantly between electric and diesel locomotion, and the growth rate in energy demand by the railway sector appears to be relatively far lower than that of the road transport sector.

IV. Alternative fuels

22. The near total dependence of the transportation system on petroleum and the fact that the transport sector already accounts for 60 per cent of final world oil consumption, together with increasing concerns about environmental impacts of petroleum combustion emissions, have strongly stimulated research and development into alternative fuels and technologies. Ranging from agricultural biofuels and alcohols to electricity and gaseous fuels, a multitude of alternative fuels for transportation are being investigated. Many Governments worldwide are providing legislative and

fiscal incentives for the development and take-up of alternative fuels and engines.

23. Alternative transportation fuels (ATF) that have attracted the most interest and are actively being tested and developed are natural gas, electricity, liquefied petroleum gas (LPG), methanol, ethanol, rape seed oil methyl ester (RME) and hydrogen. To achieve wide use it is critical that ATF characteristics meet important requirements, such as cost, availability, safety and emissions. Apparently, almost any alternative fuel vehicle (AFV) technology can serve short-range (less than 100 kilometres) duty cycles, while ethanol, methanol and LPG are currently the only potential alternative transportation fuels for long duty cycles (over 300 km) and compressed natural gas (CNG) vehicles for a range of about 300 km per day.⁷

24. Increased market penetration of electric vehicles (EV) will depend on improvements in battery-charging rates, energy densities and power densities and market factors, including cost, consumer preference and the response of manufacturers to more stringent regulations for air quality. Environmental drawbacks to the types of EVs currently in use are the emissions from power stations that generate the electricity for battery recharging, and the introduction of significant amounts of lead into the environment regardless of best efforts to recycle lead-acid batteries. There is no consensus over what type of battery may be best for the future, and a variety of battery types are being developed. About 65 per cent of electricity generated is from fossil fuels, coal, oil and natural gas. Thus, there is some potential for emissions from power stations, associated with EV-battery recharging, to be higher than from low-emission vehicles powered by gasoline or natural gas.

25. The range and performance of an EV can be considerably improved when a turbine or combustion engine is coupled in series or parallel with an electric power-train, the hybrid electric vehicle (HEV). A number of major equipment manufacturers are putting some HEV models on the market, combining electric drives and internal combustion (IC) engines. HEVs can compensate for many of the shortcomings of the pure EV, through increased range, reduced vehicle weight (i.e., less battery weight), reduced operating cost per kilometre and generally increased road performance. The disadvantages of the HEV is its complex power train and emissions from the internal combustion auxiliary power unit (APU).

26. The limitations in range and durability of batteries in EVs are avoidable with the use of fuel cells, which are well suited as APUs, given their considerably higher efficiency than that of IC engines and turbines and very low emissions.

Hydrogen is the ideal fuel for fuel cells, and methanol and natural gas and motor gasoline are also suitable after sufficient processing. There has been good progress in improving the efficiency of the fuel cell, so that power density has been improved by a factor of 6 in the past five years, with the use of platinum catalysts on each side of the fuel cell membrane and other recent breakthroughs in fuel cell technology.⁸ Two leading car manufacturers have developed fuel cell cars based on carrying the hydrogen in methanol, with a range of 250 miles between fill-ups of liquid methanol, and an innovative way has been demonstrated to rid the automotive fuel cell of its waste water. Most major automobile manufacturers are moving forward with fuel cell cars. Some use hydrogen gas tanks, while others use liquid methanol and even gasoline. Hydrogen is expensive to produce and problematic to store. Methanol reforming is relatively simple, but the reformers are still too big for cars and the distribution system is not in place. There is a distinct advantage if gasoline is reformed to produce hydrogen, because it is readily available worldwide, so that such fuel cells could be widely introduced as a practical power source in the near term. Fuel cell cars can easily outperform today's battery-powered EVs. However, a key question for a fuel cell car is the cost of the fuel cell itself. Automobile industry experts estimate that for fuel cell cars to be marketable, fuel cell costs should be US\$100 to 150 per kilowatt of capacity. In contrast, conventional gasoline engines cost about US\$35 per horsepower, or about US\$50 a kilowatt.⁹

27. EVs show potential for increasing market share in areas with strong restrictions on emissions, especially in congested urban areas and perhaps as a second family car in high-income economies. The HEV, although more complex may become an interesting AFV since it overcomes many of the shortcomings of the purely battery-powered electric car. Major car manufacturers, fuel cell manufacturers, national laboratories and universities are intensifying existing research efforts, as demonstrated in recent advances in fuel cell technology, and by forming alliances and openly linking research in the three basic areas of an AFV – power source, power plant and drive train – will probably accelerate the development of a commercially viable system. An alliance of a number of leading car manufacturers have set a target of the year 2004 for a commercial automotive fuel cell and drive train system.¹⁰ With mass production, prices will come down, but many challenges remain to be satisfactorily addressed; constraints in using fuel cells in transportation applications are considerably different and more demanding than in stationary applications, and the determination of the power

source – whether hydrogen, methanol, gasoline or some other fuel – remains problematic. A key element in the expansion of alternative fuel use is increasing the availability and convenience of alternative refuelling facilities.

28. Among the ATFs within a near-term time horizon, natural gas appears to be the most likely significant alternative to motor gasoline and diesel, particularly for use in fleets, given its abundant resources, its possibilities as a high-performance fuel, its clean burning qualities and its convenient commercial availability to end-users, especially in the major transportation consumer nations. Natural gas can be stored onboard a vehicle in pressurized tanks in either a compressed (CNG) or liquid (liquefied natural gas (LNG)) state; in the latter case, fuel tanks must be insulated as well. Currently, in the use of natural gas, emphasis is on CNG, but LNG is being increasingly looked into because of its storage benefits, although the technology for transferring LNG from a refuelling station to a vehicle and vaporizing it en route to an engine largely remains to be demonstrated.

V. Transportation and the environment

29. With the tremendous growth and the continuing high growth rates of travel and traffic around the world, it is becoming increasingly important to monitor the relationships between transportation and the environment. Transportation accounts for a substantial share of emissions of gaseous pollutants, particularly greenhouse gases, and particulate matter. Concern over air quality and greenhouse gas-induced global warming has led to actions to reduce some environmental impacts. In several OECD countries, measurable progress has been made in reducing some of those adverse environmental impacts. Technology-based strategies have been mainly applied to address the environmental impacts by improving the performance of IC engines and applying controls to motor vehicle emissions through the use of, for example, lead-free and sulphur-free gasoline; fuel additives to make fuels pollute less; and catalytic converters to reduce tailpipe emissions of gaseous pollutants, carbon monoxide, volatile organic compounds and nitrogen oxides. However, some emissions from transportation have increased, mainly carbon dioxide, the major greenhouse gas of concern, which is unavoidable since it is a by-product of fossil fuel combustion. Although this technology-based approach to mitigation of some of the impacts has worked well in some countries, the gap may further widen in the race between impacts-mitigation

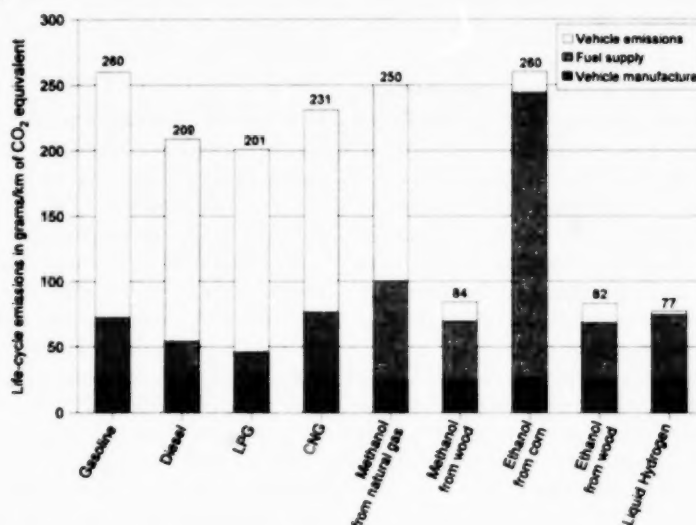
technology and the increasing demand for more transportation. Moreover, transportation activity has outpaced efficiency gains, resulting in increased energy use and thus increased carbon dioxide emissions, and the recent slowing in the rate of improvement in fuel efficiency will clearly exacerbate the problem.

30. Life-cycle emissions of a variety of transportation fuels are shown in figure IV, which should be viewed with the caveat that measuring actual emissions over the entire fuel cycle is extremely difficult, and dated material and assumptions are unavoidable. Synthetic liquid fuels derived from fossil fuels, including some biomass-derived fuels, provide little or no reduction in greenhouse gas emissions. LPG and CNG in optimized engines can reduce emissions relatively by about 10 to 25 per cent. Methanol and ethanol from wood or other low-input biomass feedstock, which have yet to be technically demonstrated on a large-scale basis, could result in greenhouse gas emissions of about 60 to 80 per cent. A large-scale replacement of the current fossil-fuel-based transportation system by fuels derived from completely renewable sources of energy, including hydrogen from electrolysis of water and EVs powered by electricity from renewable energy sources, could result in over 80 per cent reduction of greenhouse gas emissions from transportation fuels.

31. It is apparent that the greenhouse gas advantage of alternative fuels is drastically reduced by energy use in the upstream processing of alternative fuels. Even battery-powered EVs provide little or no benefit if the electricity is generated from fossil fuels. Therefore, unless there is a widespread switch to cellulosic ethanol from woody plants or to carbon dioxide-emission-free energy sources, such as solar, wind and nuclear energy and hydropower, even large market penetrations of alternative fuels could have little effect on emissions of greenhouse gases from transportation activity.

32. Considering the fast-rising share of transportation fuels in world total oil demand noted in section III above, a reduction in the use of petroleum-based transportation fuels by switching to alternative fuels would lead to a lower growth rate in world demand for oil and thus substantially moderate the increase in global carbon dioxide emissions. Given their vast resources in technology, human resources, manufacturing and finance, there is ample opportunity for fuel switching in the near term in the industrial nations, and consequently for influencing the pattern of demand for transportation fuels in developing countries.

Figure IV
Life-cycle greenhouse gas emissions of various automotive fuels^a



Source: Organisation for Economic Cooperation and Development, *Cars and Climate Change* (1993).

^a Based on North American vehicles and energy supply system.

VI. Conclusions and suggestions for further action

33. Petroleum demand in the transportation sector will continue to increase substantially for the next 20 years, since the transportation sector will remain reliant on petroleum-based fuels during this time. As crude oil supply is expected to be fully sufficient to meet total world oil demand through 2030, including any surge in transportation fuel demand, oil price developments that would influence a shift to alternative transportation fuels and substantially increase its widespread use, cannot be reasonably expected in the near term. Moreover, the existing stock of transport equipment will limit opportunities for fuel switching. Thus, market instruments and other measures, such as fiscal incentives and regulations, will be needed to encourage faster uptake of alternative fuels.

34. Evidently, Governments have a significant role to play in reducing the environmental impacts of the transportation sector by putting in place and implementing a transportation sector energy policy that promotes improvements in transportation efficiency and use of alternative fuels. Particularly for the reduction of greenhouse gas emissions,

the main thrust of a transportation sector energy policy should be on increasing efficiency and fuel flexibility: promote short-term efficiency improvements, develop markets for alternative fuels, develop technologies for alternative fuel vehicles and reduce the demand for travel. Widespread introduction of alternative fuels will need special assistance: compared with gasoline and diesel fuels, such fuels require different refuelling infrastructure, vehicle fuel storage mechanisms, and engine and emission control technologies.

35. Due to recent environmental concerns but also prompted earlier by fiscal considerations and concerns over security of supply, most OECD countries have used market instruments to restrain fuel and motor vehicle use. Policy measures have also led to substantial reductions in gaseous (other than carbon dioxide) and particulate emissions from petroleum combustion in the transportation sector. However, many other policies and some deep-rooted social forces, such as an affinity for cars and a preference for private conveyance, have increased both the amount of fuel used by cars and the distances people drive them. In developing countries, although there are emission control measures comparable to those of OECD countries in place in some major cities, enforcement procedures are apparently not

adequate. Increasing population, urbanization and per capita income in developing countries will increase demand for and affect the nature of passenger transport; thus, strict control of emission standards is needed.

36. Market instruments and policy measures need to be applied evenly to all types of IC engines, whether mobile or fixed, large or small, or powered by gasoline, diesel or other petroleum-based fuels. For example, the efficiency of an average new car has improved to such an extent that it is estimated that running a lawn mower at home for an hour produces as much pollution as driving a new car for 2,000 km. And diesel-fuelled buses and trucks are allowed to operate at lower emission standards, especially for particulate emissions that are proven serious health hazards. Moreover, it is evident that in the largest energy-using transportation modes, improvements in efficiency have slowed, and there is therefore a need to reverse this trend.

37. Significant reductions in greenhouse gas emissions can be achieved in the transportation sector by improving the efficiency of drive trains, body shape and materials used in all vehicles, and by switching to alternative and improved fuels. In these key areas, changes in OECD countries can clearly influence the pattern of demand for transportation services in the rest of the world.

38. There are a wide number of possible policies for reducing the negative environmental and social impacts of transportation. A taxonomy of such policies could include the following: (a) measures to reduce demand; (b) measures to encourage change of transportation modes; (c) measures to raise energy efficiency within each transportation modes; and (d) measures to promote alternative fuels. In its report for the 1997 review of the Rio commitments, the High-Level Advisory Board on Sustainable Development concluded that the best prospect for securing significant gains in the transport sector would be through a combination of such policy measures, and it provided examples of several of them that together could constitute a programme of action. The Board also recommended that Governments give serious intention to launching such a programme of action at the international level. The Board further recommended that the programme of action be targeted on several cities in the various regions of the developing world, with international collaboration between city authorities, urban planners and bilateral and multilateral sources of finance, with a view to developing blueprints for implementing such schemes by the year 2002 (see E/CN.17/1997/17/Add.1).

Notes

- ¹ United States Department of Transportation, *Transportation Statistics Annual Report 1997* (Washington, D.C., 1997), table 2.1a
- ² Statistics on the consumption of major transportation fuels in the present report are taken from *Energy Statistics Yearbook* (United Nations publication), various issues, and *Energy Statistics and Balances of Non-OECD Countries and Energy Balances of OECD Countries* (Paris, OECD), various issues.
- ³ See *Energy Balances of OECD Countries* (Paris, OECD), 1991-1992 and 1994 issues.
- ⁴ See United States Department of Transportation, *op cit.*, chap. 4, p. 85.
- ⁵ See "Sustainable development: OECD approaches", contribution of OECD to the seventeenth special session of the General Assembly (Paris, OECD, 1997).
- ⁶ See World Energy Council, *Global Transport Sector Energy Demand Towards 2020* (London, 1995).
- ⁷ For an in-depth analysis and discussion of alternative fuels and technology, see United States Department of Energy, Energy Information Agency, "Alternatives to traditional transportation fuels: an overview" (Washington, D.C., 1994).
- ⁸ See "Hydrogen, fuel for the twenty-first century?", *Energy Economist*, November 1996; and *New York Times*, 8 October 1997, p. D 1.
- ⁹ *New York Times*, 21 October 1997, p. D 1.
- ¹⁰ *Ibid.*, 16 December 1997, p. D 1.

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Energy and sustainable development

**Coordination of activities of the organizations in the United
Nations system in the field of energy****Report of the Secretary-General****Contents**

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I. Introduction

1. The Committee on New and Renewable Sources of Energy and on Energy for Development, at its second session, in February 1996, requested the Secretary-General to prepare a report on coordination in energy for consideration by the Committee at its third session in 1998.¹ The Economic and Social Council, at its substantive session of 1996, approved the provisional agenda and documentation for the third session of the Committee, as amended (see A/51/3 (part II)). The present report has been prepared in response to that request.

II. Activities of the United Nations system in the field of energy

2. An overview of the policies and programmes as well as activities by respective entities of the United Nations system is contained in the earlier reports of the Secretary-General (see E/CN.17/1997/7 and Corr.1 and A/52/175-E/1997/75). These will be made available to the Committee at its third session. Policy discussions take place in various intergovernmental bodies, such as the Committee on New and Renewable Sources of Energy and on Energy for Development, the Commission on Sustainable Development, the Economic and Social Council, the Second Committee of the General Assembly and other legislative bodies of the respective entities of the United Nations system.

3. A wide range of activities have been reported by the respective entities of the United Nations system, reflecting the mandates, policies and programmes of these entities. Details of the activities are contained in the annex to the report of the Secretary-General on inventory of energy-related programmes and activities of entities within the United Nations system to the Commission on Sustainable Development. The means of implementation of the programmes and activities have involved the preparation of studies and reports, technical assistance, organization and training of workshops, as well as seminars and conferences, institution and capacity-building for the assessment of resources, policy formulation, planning, analysis and data management and a provision of financial assistance.

4. The current policies, programmes and activities of the entities within the United Nations system in the field of energy largely emanate from the outcome of the United Nations Conference on New and Renewable Sources of Energy, held at Nairobi, in 1981. Furthermore, in the light of the outcome of the United Nations Conference on

Environment and Development (UNCED) held at Rio de Janeiro in June 1992, many entities have adjusted their programmes, projects and activities in varying degrees. UNCED emphasized the key role that energy plays in achieving the economic, social and environmental objectives of sustainable development, and stressed that the development and use of energy resources, and technologies should be realized in a socially acceptable manner. The activities of the respective entities of the United Nations system have since emphasized the relation between energy and sustainable development, and have, in varying degrees, espoused, *inter alia*, (a) increased efficiency in energy and material use, and (b) enhanced development and use of renewable sources of energy.

III. Cooperation and coordination of activities within the United Nations system in the field of energy

5. The need for cooperation and coordination of activities of the entities within the United Nations system, including those on energy, has been emphasized time and again over the years. Enhancing better coordination of activities at the national level has been of interest to the United Nations for a long time, given the fact that the main focus of development activities is at the country level where programmes are deployed in support of national priorities. Such a move will ensure relevance and foster the successful development of national capacity.

6. Although, on the basis of the available information, there appears to be cooperation and coordination of activities in the field of energy among the entities within the United Nations system, the nature of such activities is somewhat ad hoc and a common strategy is lacking. In particular, many activities in energy are undertaken at the country level, and cooperation in the development and implementation of those activities in response to the local situation appear to be minimal and would benefit greatly from a common strategy and enhanced sharing of experience.

7. At its nineteenth special session, the General Assembly stressed the need for encouraging better coordination on the issue of energy within the United Nations system and agreed, *inter alia*, that the work of the Committee should be more compatible with and supportive of the work of the Commission on Sustainable Development (see A/S-19/29, para. 135).

8. The Inter-Agency Committee on Sustainable Development has also emphasized the importance of

cooperation and coordination of activities within the United Nations system, including those on energy. It decided that specific measures to achieve inter-agency collaboration would be accomplished through (a) preparation of guidelines/manuals/methodologies or similar materials on national development; (b) organization of a series of sustainable development workshops; and (c) more systematic approach to the collection and dissemination of information on relevant topics. Accordingly, letters soliciting information on the above programmes were sent to respective entities of the United Nations system.

9. The merger of the three United Nations departments working in the economic and social fields into the Department of Economic and Social Affairs provides a good opportunity to bring together the United Nations Secretariat's analytical, normative and technical capacities, which should enrich both the policy and technical cooperation of the United Nations activities in various fields, including energy.

10. In recent years, further attempts have been made to enhance cooperation and coordination of activities within the United Nations system. An ad hoc Inter-agency Group on Energy was constituted in March 1996. It has held several meetings, one each in New York (March 1996), Geneva (September 1996), Paris (December 1996) and Vienna (October 1997). The meetings have provided an opportunity to discuss a range of issues, including specific activities and programmes of individual entities of the United Nations system and how these can be better coordinated. Emphasis has been made on better exchange of information, including improved access to and development as well as expansion of World Wide Web sites on energy, and cooperation in the formulation and implementation of projects and programmes, including their joint implementation. One of the issues that has generated a great deal of interest and discussion is that of the development of a common approach within the United Nations system on issues relating to energy. The topic was discussed at length in September and December 1996 at Geneva and in Paris, and more recently, in October 1997 at Vienna. The discussions on the development of a common approach are reflected in the report of the Secretary-General to the fifth session of the Commission on Sustainable Development. In 1996, at Geneva and in Paris, the Group cooperated in the preparation of the above-mentioned report of the Secretary-General on an inventory of ongoing energy-related programmes and activities within the United Nations system for submission to the Commission on Sustainable Development at its fifth session. At its tenth session, at Geneva (17-19 September 1997), the Inter-Agency Committee on Sustainable

Development stressed the need to ensure stronger focus on intergovernmental collaboration on the practical implementation of relevant activities, in particular, at the country level.

11. As part of preparations for the ninth session of the Commission on Sustainable Development in 2001, which will be largely devoted to energy, the United Nations Development Programme (UNDP) organized an ad hoc brainstorming meeting in October 1997 aimed at identifying key issues for consideration at the meeting. A number of these issues were later discussed and elaborated upon at the ad hoc Inter-agency Group on Energy at Vienna in 1997, which, *inter alia*, agreed to the idea of the creation of a global forum on sustainable energy to foster an enhanced dialogue among Governments, international organizations, the business community, non-governmental organizations, and the academic community, as suggested in the joint report referred to below. As part of this cooperative effort, UNDP and the Department have prepared a joint report entitled "Energy and sustainable development: draft discussion paper on key issues and required actions", which is intended to help in identifying, clarifying and articulating key issues to be addressed by the intergovernmental process at the ninth session of the Commission.

IV. Recommendations

12. The following recommendations draw heavily on those contained in the reports of the Secretary-General to the Commission on Sustainable Development at its fifth session and to the General Assembly at its fifty-second session. In the above-mentioned reports, it was suggested that coordination and cooperation should be enhanced through the following actions:

(a) Convening ad hoc meetings of the entities within the United Nations system dealing with energy in order for them to elaborate a common reference framework for actions in the field of energy and to achieve coherence and effectiveness in energy activities that contribute to sustainable development (this issue was discussed by the Commission and recommended for further consideration by the General Assembly at its nineteenth session in June 1997); to enhance the exchange of information on the different aspects of energy development and use, including policy issues; and to help in the improvement of energy data and information systems of the respective organizations;

(b) Devoting part of the agenda of the sessions of the Inter-Agency Committee on Sustainable Development

to energy on a regular basis, and ensuring linkages with energy-related aspects of the work of other Administrative Committee on Coordination bodies;

(c) Cooperating with organizations outside the United Nations system in the field of energy;

(d) Encouraging joint programming and implementation of energy activities of common interest to the entities within the United Nations system.

Notes

¹ See *Official Records of the Economic and Social Council, 1996, Supplement No. 4*.